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CLARK FORK RIVER
SITE SCREENING STUDY

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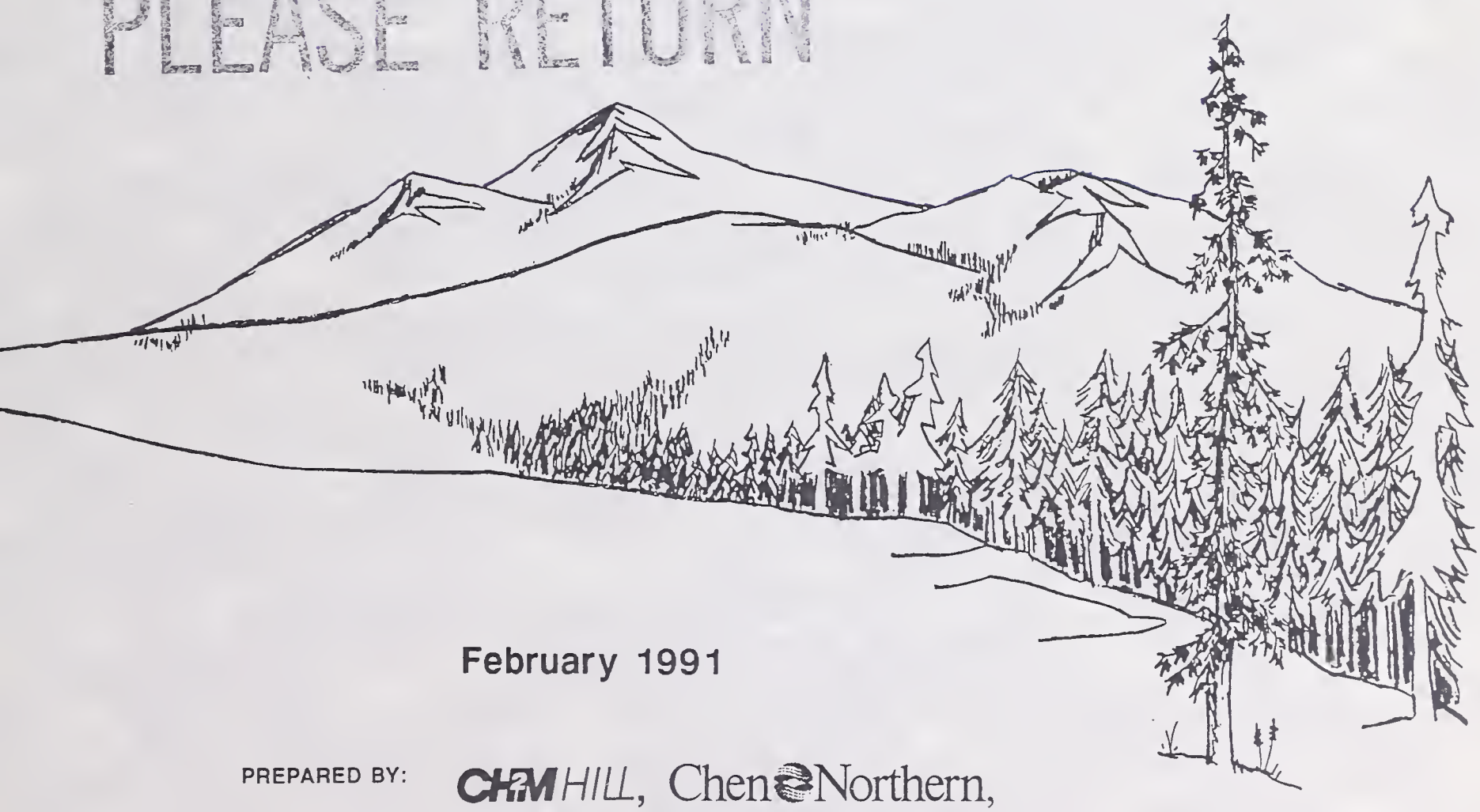

February 1991

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DATA SUMMARY REPORT
UPPER CLARK FORK RIVER SCREENING STUDY

VOLUME I
TEXT

EPA REGION VIII

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EXECUTIVE SUMMARY

A site screening study was completed on the reach of the Upper Clark Fork River from the Warm Springs Ponds, located near Warm Springs, Montana to the Milltown Reservoir, located near Milltown, Montana. Existing data concerning land use and available environmental data for the study area were collated and are included in this report. Groundwater and soils sampling was completed as part of this investigation; planned surface water sampling was not completed because of the lack of high flows in the Upper Clark Fork River during the period of study (1987).

A planned component of this site screening study was an analysis of the extent of exposed tailings and contaminated soils using remote sensing techniques. This task was not completed and, hence, results of this type of analysis are not included in this report.

Objectives of the Clark Fork River site screening study were to: (1) collate and collect sufficient environmental data to efficiently plan and conduct a comprehensive remedial investigation/feasibility study for the study area; (2) provide sufficient data and information for use in identifying operable units within the study area; and, (3) provide a rational basis to prioritize remedial investigation/feasibility study activities within the study area.

Existing information was assembled to delineate the following site characteristics:

- Drainage basins
- Sampling locations
- Land use
- Irrigated areas
- Domestic wells
- Mining districts
- Geothermal springs
- Demography
- Extent of tailings
- River gradient

Results of the data collation effort are contained in this report and are illustrated through a series of oversized maps which accompany the report.

Groundwater investigations focused on inventorying and sampling existing stock, irrigation, and domestic wells located adjacent to the Clark Fork River. Over 500 wells were included in the well inventory; approximately twice that number are present within the study area. Approximately 80 of the inventoried wells were sampled for metals and major ion parameters. Analytical data resulting from this sampling effort indicate only one well sampled exceeded a primary drinking water maximum contaminant level (MCL); the standard exceeded was for cadmium. Several wells sampled exceeded secondary drinking water MCLs for iron, manganese, and sulfate.

Ten monitoring wells were also installed and sampled as part of this investigation. Monitoring wells were sited at locations characterized by either exposed or buried tailing deposits. Results of this sampling effort indicated exceedances of primary drinking water

MCLs for arsenic and cadmium were measured in a monitoring well located near the Galen Bridge. Secondary drinking water MCL exceedances of manganese, iron, and sulfate were measured in eight of nine monitoring wells sampled. Analytical data for monitoring wells constructed cross valley indicate groundwater quality improves somewhat toward the Clark Fork River.

Groundwater level data obtained in conjunction with measurements of stage in the Clark Fork River indicate the Clark Fork River generally gains flow from the adjacent groundwater system. An exception to this trend is a measured reversal in water gradient from the Clark Fork River to the adjacent groundwater system near Perkins Lane Bridge, located north of the Warm Springs Ponds. Losing conditions in the Clark Fork River at this location began sometime in January, 1988 and continued through spring. Locating losing reaches of the Clark Fork River may be important in identifying operable units within the study area because of the potential change in groundwater chemistry associated with this process. Groundwater samples were not collected during time periods of losing stream conditions in the Clark Fork River.

Soil and vegetation investigations completed in conjunction with the Clark Fork River screening study focused on determining the range of environmental conditions present within the study area. A portable X-ray fluorescence (XRF) analyzer was used to assist in this effort. A corollary purpose to the investigation was to determine if the level of metal contamination present within the study area could be accurately measured with this instrument in the field.

Twelve sample sites were selected for detailed analysis during the soil and vegetation investigation. Sites were selected using aerial photographs, tailings deposition maps, previously collected information, and data collected during a preliminary survey of the study area. For each of the twelve sites, soil samples were collected from various depths, analyzed with the XRF, and shipped to an analytical laboratory for determinations of pH, EC, and total concentrations of arsenic, copper, iron, lead, and zinc. Values derived from the XRF analyses were compared statistically to the laboratory derived values to determine if a relationship existed between these variables. Vegetation was evaluated at each site in terms of canopy cover and above ground production.

Summary results of the soil and vegetation portion of this investigation are presented by Site Type in Table ES-1. Correlations between XRF values and laboratory determined metal concentrations were high for sites having relatively high concentrations of the target elements. This indicated that for these types of sites, the portable XRF spectrometer can be a reliable indicator of the concentrations of these elements. However, at sites exhibiting relatively low soils metal concentrations, correlations between the XRF and laboratory determined values were poor, indicating that the XRF spectrometer was less reliable for these sites.

TABLE ES-1

RESULTS SUMMARY FOR THE SOILS AND VEGETATION PORTION OF THE CLARK FORK RIVER SCREEN STUDY

Site Type	Level of Contamination[1]	Plant Performance[2]	Reliability of Using the XRF to Determine Soil/Tailings Metal Concentrations
Background[3] 1 site 20 samples	None As = 16.0 ± 11 Cu = 29.0 ± 10	Excellent C = 95% P = 2800	Poor, due to low concentrations of the target elements in the soil
Good Plant Growth 2 sites 40 samples	None to low As = 34 ± 15 Cu = 221 ± 369	Very good to excellent C = 100% P = 2900	Poor, due to low concentrations of the target elements in the soil
Bare Tailings 3 sites 60 samples	High As = 523 ± 450 Cu = 4504 ± 8499	Poor to good C = 43% P = 1900	Excellent, due to high concentrations of the target elements in the tailings
Buried Tailings 4 sites 65 samples	Moderate to high As = 419 ± 348 Cu = 2702 ± 2188	Very good to excellent C = 85% P = 1900	Excellent, due to high concentrations of the target elements in the tailings
Historically Irrigated 2 sites 40 samples	Moderate to high As = 105 ± 51 Cu = 1216 ± 503	Poor to good C = 50% P = 1300	Good to excellent depending on the concentrations of the target elements in the soil

1 Metal contamination relative to the background site (Site 14). Mean ± standard deviation for laboratory determined arsenic (As) and copper (Cu) concentrations (ug/g).

2 Plant performance rating was based on mean plant canopy (C): 0-20% = very poor, 21-40% = poor, 41-60% = good, 61-80% = very good, ≥81% = excellent. P = mean aboveground plant production in kg/ha.

3 Soils at the background site (Site 14 of this study) were not anthropogenically enriched.

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2	Drainage Basins
3	Mining Districts
4	Sampling Locations and Geothermal Springs
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1	Clark Fork River Channel and Valley Bottom Gradients

1.0 INTRODUCTION

1.1 PURPOSE

This report presents and summarizes environmental and land use data collected and collated during a screening study conducted during 1987 on the reach of the Clark Fork River between the Warm Springs Treatment Ponds, near Warm Springs, Montana and Milltown Reservoir, located near Milltown, Montana (Figure 1-1). Work tasks described in this report were conducted under the auspices of a site screening study plan (CH2M HILL, 1987a) and in accordance with approved field operations plans (CH2M HILL, 1987b, 1987c, 1987d), a quality assurance project plan (CH2M HILL, 1987e), and a laboratory analytical protocol plan (CH2M HILL, 1987f).

A separate but interrelated remote sensing investigation was also scheduled to be completed during this screening study by Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV) personnel. Because of technical and contractual difficulties, EMSL-LV personnel were unable to produce the remote sensing information for this project. Production of this report has been delayed since 1987 while attempts were made to resolve these difficulties. The Montana Department of Health and Environmental Sciences (MDHES) has elected to issue this report without the remote sensing data.

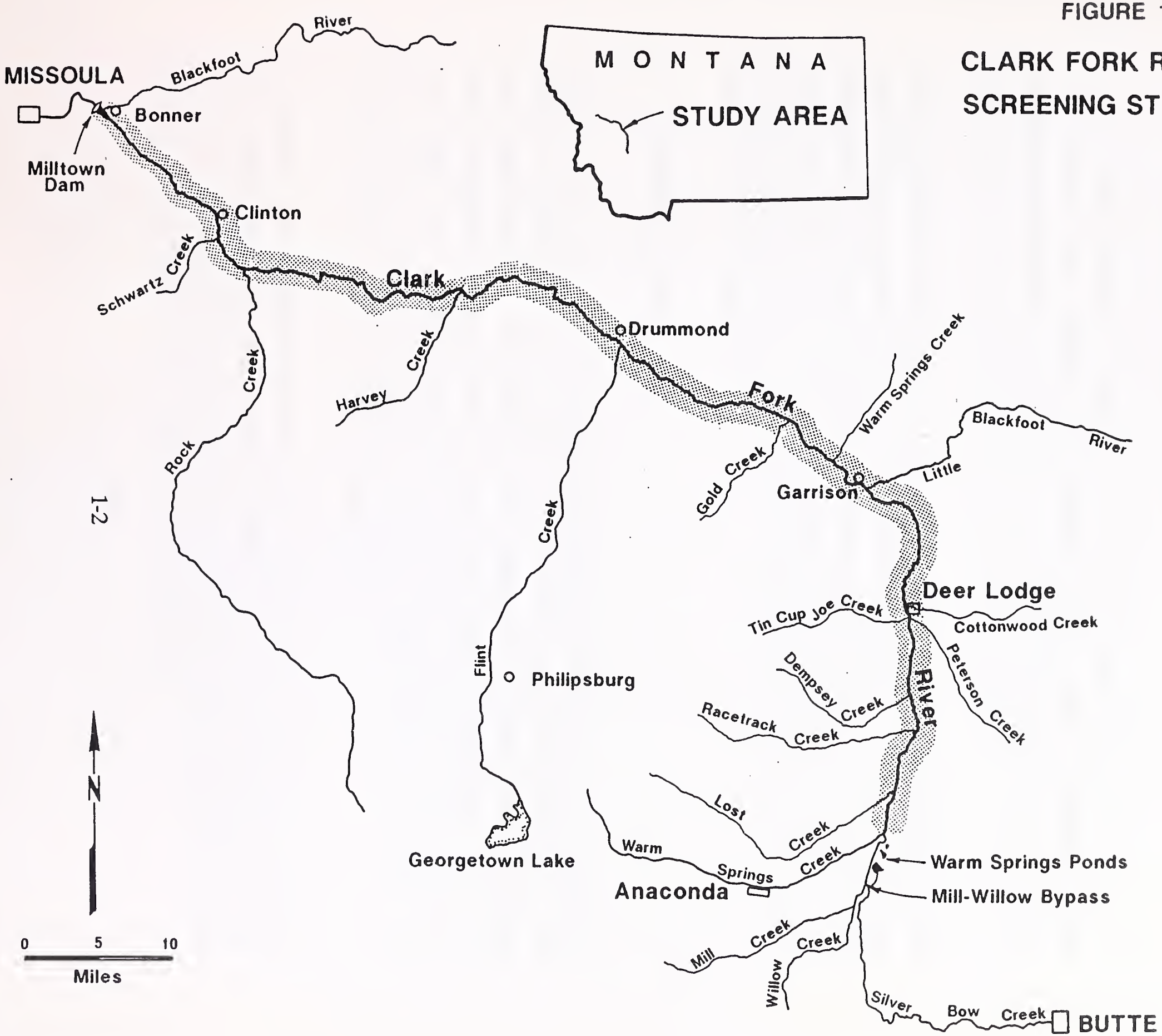
1.2 PROJECT OBJECTIVES

Objectives to completing an environmental screening study on the upper Clark Fork River included:

- Collect baseline environmental information necessary to efficiently plan and conduct a comprehensive remedial investigation/feasibility study for the study area which fully addresses the requirements of the National Contingency Plan and EPA's guidance for these type of activities.

FIGURE 1-1

CLARK FORK RIVER SITE SCREENING STUDY AREA



- Provide data and information to assist in the preliminary identification of operable units within this study area.

- Provide a rational basis to prioritize remedial investigation/feasibility study activities within the study area.

To meet project objectives, environmental data including surface water, groundwater, and soils information were collected from throughout the study area. In addition, existing information was collated to better describe current and historical land use in the study area. Data resulting from these efforts are presented and discussed herein.

Because production of this report has been delayed since 1987, a separate section of this report has been prepared (Section 4.0) to identify environmental studies that have been completed in the Upper Clark Fork River Basin since that time. Such information will provide the reader with a more comprehensive understanding of the current level of knowledge of the study area. The general objectives of this study, however, remain unchanged from that described above.

1.3 PROJECT BACKGROUND

The study area for the Clark Fork River screening study extends from Warm Springs to Milltown, Montana (Figure 1-1). The study area includes areas directly adjacent to the upper Clark Fork River. The Clark Fork River begins at the confluence of Warm Springs Creek, the Mill-Willow Bypass, and the outfall from the Warm Springs Ponds. Silver Bow Creek, which enters the Warm Springs Ponds from the south, and the upper Clark Fork River have been affected by extensive mining and milling activity in the Butte and Anaconda, Montana areas over the last hundred years.

The primary contaminants of concern in the study area are heavy metals, particularly copper, zinc, cadmium, lead, arsenic, and iron. The primary sources of contamination within the study area are fluvially deposited mining and milling wastes which are found on the land surface, buried in discrete layers, or mixed with the native soil.

Bare tailings, by their nature and proximity to the Clark Fork River, are easily erodible by either wind or water. As such, tailing deposits along the Clark Fork River pose a potentially acute environmental hazard during high flow periods; elevated metals levels during low flow periods may also have chronic effects on aquatic life. As well, land irrigated with contaminated water may have reduced productivity and subjacent groundwater quality may be degraded locally because of these sources of contamination.

In 1983, the U.S. Environmental Protection Agency (EPA) named Silver Bow Creek and contiguous portions of the upper Clark Fork River (to the town of Deer Lodge) as a Superfund site under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). Since that time, investigations have indicated that even a larger portion of the Clark Fork River (between Deer Lodge and Milltown Reservoir) has been degraded by historical mining activities. The Montana Department of Health and Environmental Sciences (MDHES) in association with the EPA elected to extend the CERCLA site study area from Deer Lodge to the Milltown Reservoir and make the upper Clark Fork River from Warm Springs to Milltown a separate study area.

In 1990, during preparation of the ecological risk assessment work plans for the Milltown Reservoir Sediments Superfund site, EPA elected to include the Upper Clark Fork River study area as part of the Milltown National Priorities List (NPL) site. In addition, EPA has taken the lead status for the site.

SECTION 2.0

2.0 ASSEMBLY OF EXISTING INFORMATION

Existing information was collected and collated for the Clark Fork River screening study to provide a basis from which work plans and field documents could be generated should the site undergo the remedial investigation/feasibility study process. Types of information assembled included the following:

- Drainage basins -- First order drainage basin boundaries of tributaries to the Upper Clark Fork River were identified on topographic base maps of the study area.

- Mining districts -- Historical and active mining districts within the drainage basins identified above were located and identified on base maps of the study area.

- Environmental sampling locations -- Locations of surface water, groundwater, fisheries, and aquatic invertebrates sampling sites along the Clark Fork River were assembled and plotted on base maps of the study area.

- Geothermal springs -- Locations of these features were researched through the scientific literature and were identified on base maps of the study area.

- Land use and demography -- Use of lands in areas adjacent to the Clark Fork River was researched and identified on a base map of the study area. Locations and populations of concentrations of persons living in and adjacent to the study area were likewise researched and plotted on the project base map.

- Irrigation -- Locations of historic and active irrigation ditches which derived water from the Clark Fork River were delineated on a base map of the study area. In addition, areas irrigated by the identified ditches were determined and illustrated on a map.

- Extent of tailings -- Available existing literature and maps were reviewed to delineate the extent of fluvially deposited tailings along the Clark Fork River. Recent aerial photography of the study area was reviewed to determine locations of tailing deposits within the study area where existing information was deemed inadequate.

- Domestic wells -- Locations of domestic and monitoring wells adjacent to the Clark Fork River were identified and plotted on a base map of the study area.

- Clark Fork River gradient -- The gradient of the Upper Clark Fork River was determined through analysis of available topographic base maps of the study area. This information was plotted in profile fashion relating river bottom and valley bottom elevations to distance.

2.1 OBJECTIVES

The primary objectives in assembling information described above were to create a series of maps which would illustrate existing information germane to planning and executing a remedial investigation/feasibility study on the Upper Clark Fork River. These types of information are necessary to focus any data gathering efforts at the site and to provide a basis for evaluating any human health and environmental impacts associated with the Upper Clark River River system.

2.2 CHANGES TO THE ORIGINAL WORK PLAN

No changes to the original work plan resulted from completion of the assemblage of existing information work task.

2.3 RESULTS

Available information gathered pertaining to topics described above are illustrated on a series of oversized maps and exhibits included in Volume 3 of this report. Map and Exhibit numbers and corresponding subject matter include the following:

MAP NO.	SUBJECT MATTER
1	Index Map
2	Drainage Basins
3	Mining Districts
4	Sampling Locations, Geothermal Springs
5	Land Use and Demography
6	Irrigation Ditches, Irrigated Areas
7	Extent of Tailings, Well Locations

EXHIBIT NO.	SUBJECT MATTER
1	Clark Fork River Channel Gradient

Data presented on the foregoing maps and exhibits indicate the following:

- Major drainage basins tributary to the Upper Clark Fork River within the study area include Silver Bow Creek, Warm Springs Creek, Little Blackfoot River, Gold Creek, Flint Creek, and Rock Creek (Map 2, Oversize).

- The greatest density of mining districts in areas tributary to the Upper Clark Fork River are located in the Butte area and in the Flint Creek Range between the towns of Philipsburg and Deer Lodge (Map 3, Oversize). Other mining districts are present along the Continental Divide, within the Garnet and Sapphire Ranges, and within the John Long Mountains.

- Surface water sampling sites are located throughout the Upper Clark Fork River. The most frequently sampled sites are generally located in the Deer Lodge Valley between Warm Springs and Garrison (Map 4, Oversize). Five geothermal springs were identified adjacent to the Upper Clark Fork River. These include two in the Deer Lodge Valley (Warm Springs and Deer Lodge Prison Hot Springs), one located near Garrison (Garrison Warm Springs) and two located near Bearmouth (Bearmouth Hot Springs and Nimrod Springs) (Map 4, Oversize).

- The primary land use within and adjacent to the study area is agriculture, including both irrigated hay and alfalfa production and grazing (Map 5, Oversize). Most of the study area is privately owned, the majority of public lands are present in the lower one-third of the study area near Milltown Dam. Several campgrounds, recreation areas, and fishing access sites are present within the study area.

- The area with the largest concentration of people living within and adjacent to the Upper Clark Fork River is in Deer Lodge (population approximately 4000) (Map 5, Oversize). Other population centers in the Deer Lodge Valley include Warm Springs, Galen, Dempsey, the State Prison, and Garrison. Populated areas within the middle reaches of the study area include Gold Creek, Drummond, and Bearmouth. Rock Creek, Clinton, Piltzville, and Turah are population centers in the lower reaches of the study area. The combined population of these towns/areas is approximately 3000. Numerous isolated residences are located between these areas of population concentration.

- Irrigation water withdrawal from the Upper Clark Fork River occurs at numerous points within the study area. The largest acreage of lands which have been irrigated with Clark Fork River water occur in the Deer Lodge Valley and adjacent to the reach of river between Gold Creek and Drummond (Map 6, Oversize). Irrigation practices have been discontinued

at only a few isolated areas within the study area. The total area of lands which have received irrigation water from the Clark Fork River within the study area is approximately 14,600 acres.

- Analyses of existing soils maps and recent aerial photography indicate fluvially deposited tailings are present along the Upper Clark Fork River, primarily in the reach of river between Warm Springs and Garrison (Map 7, Oversize). Metals enriched soils may be present along the river between Garrison and Milltown. The lateral extent of exposed tailing deposits is generally limited to the first and second terraces above the Clark Fork River. The total area of metals enriched soils, as depicted on Map 7 (Oversize) is approximately 9,000 acres. Irrigation activities may have historically transported tailings-laden river water to areas further from the river.

- Locations of numerous wells were identified within or directly adjacent to the Upper Clark Fork River floodplain. The greatest concentrations of domestic wells are located in the area south of Deer Lodge, in and near Drummond, and in the Piltzville-Turah area (Map 7, Oversize). Very few domestic wells were identified as being completed in near-surface aquifers located directly beneath exposed tailing deposits.

- The Clark Fork River channel gradient profile (Exhibit 1, Oversize) indicates two general reaches of steepened gradients. These include the reach of the river from below the Little Blackfoot River to below Gold Creek and the reach of river from Rock Creek to Milltown Dam (Exhibit 1, Oversize). Valley bottom gradients within the study area also exhibit these same general areas of steepened gradients. Reaches of the Upper Clark Fork River exhibiting greatest sinuosity occur primarily in the Upper Deer Lodge Valley, above the town of Deer Lodge.

SECTION 3.

3.0 FIELD ACTIVITIES

Field activities associated with the Clark Fork River screening study included investigations of surface water, groundwater, and soils. Descriptions of these investigations and summaries of resultant data are provided in the following sections.

3.1 SURFACE WATER INVESTIGATION

This section of the report describes various components of surface water investigations associated with the Clark Fork River screening study, objectives of the surface water work tasks, changes to the original surface water work plan and the effects of those changes, and summarizes data collected during the surface water investigation.

3.1.1 High Flow Sampling

The primary surface water investigation work task for the Clark Fork River screening study was the planned collection of surface water samples during high flow conditions. Surface water sampling was to be conducted at 28 sites along the Clark Fork River and its tributaries on two separate occasions during high flow conditions. Proposed sampling sites included 15 on the main stem Clark Fork River and 13 tributary sites. Sample site locations were selected based upon: (1) the desire to characterize water quality throughout the entire study area; (2) the need to characterize potential impacts of tributaries on the main stem stream; (3) the desire to sample sites which had previously been sampled; and (4) site accessibility.

3.1.1.1 Objectives

The objective of the surface water sampling effort was to obtain samples of a slug of water as it moved downstream during high flow conditions in response to spring snowmelt. This sampling plan was developed to evaluate changes in various water quality parameters due to tributary inflows to the Clark Fork River in various reaches of the system. It was anticipated that sampling and flow measurements would be completed on the Clark Fork

River with a crane and reel operating from bridges and by using wading techniques on tributaries.

3.1.1.2 Changes to the Original Study Plan

Because streamflow in the Clark Fork River was well below normal during 1987, surface water sampling was not completed. It was determined that sufficient low to medium flow water quality data were available to describe conditions in the stream; hence, collection of additional samples during flow conditions which occurred during 1987 was deemed unnecessary. Figure 3-1 illustrates flow hydrographs for the Clark Fork River during 1987 as compared to historic averages.

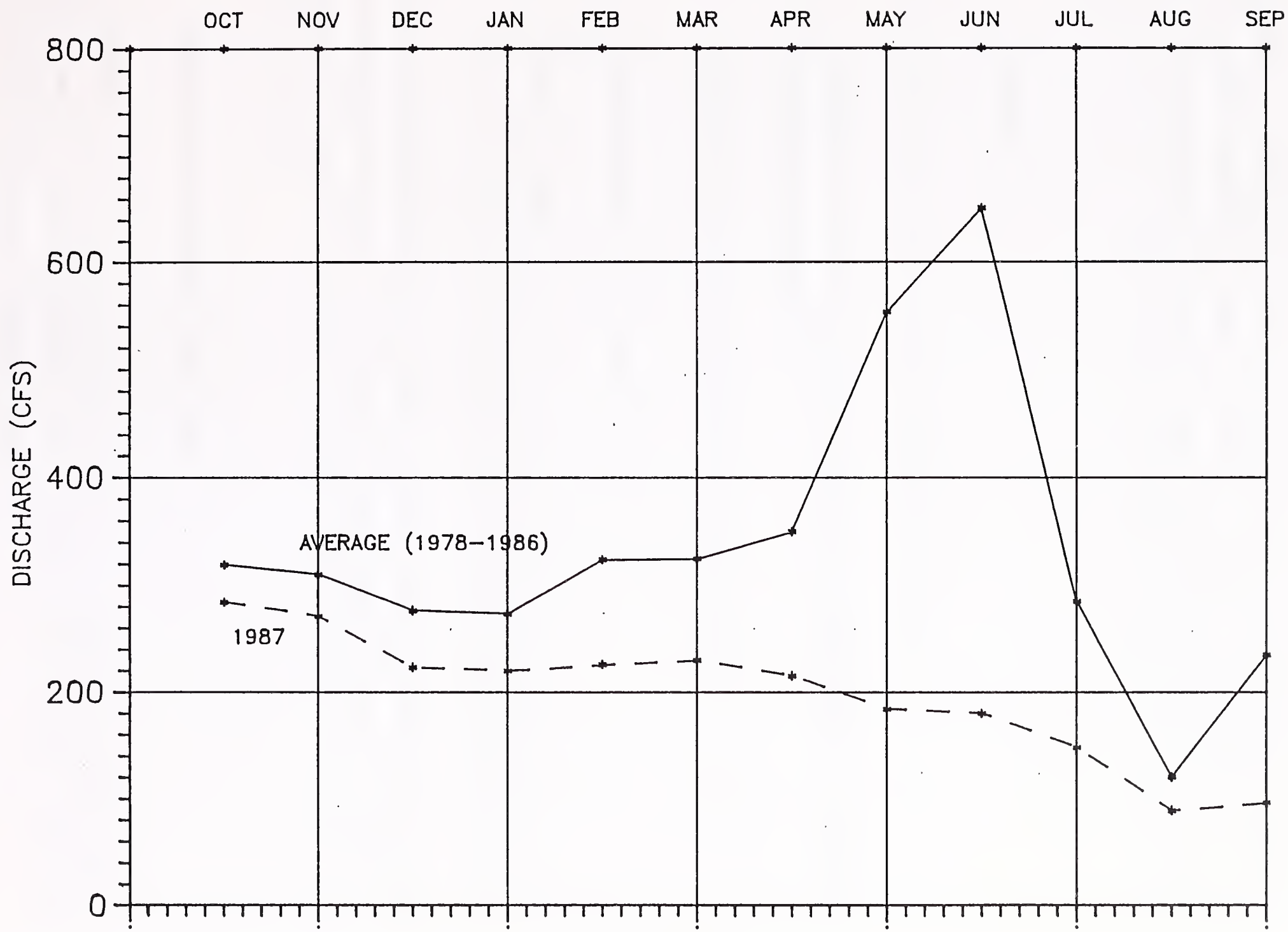
3.1.1.3 Results

No data were collected for this task because of the lack of spring high flow conditions in the Clark Fork River during 1987. The result of the failure to sample the Clark Fork River and its tributaries during 1987 is that adequate data are still not available to characterize the quality of the river during high flow periods.

3.2 GROUNDWATER INVESTIGATIONS

This section of the report describes various components of groundwater investigations associated with the Clark Fork River screening study, objectives of the groundwater work tasks, changes to the original groundwater work plan and the effects of those changes, and presents and summarizes data collected during the groundwater investigation. The groundwater investigation consisted of three general components: (1) inventorying domestic wells; (2) domestic well sampling; and (3) installing and sampling ten monitoring wells located in the Clark Fork River alluvial aquifer beneath exposed tailing deposits.

FIGURE 3–1 CLARK FORK RIVER AVERAGE MONTHLY HYDROGRAPH AT DEER LODGE



3.2.1 Well Inventory

A well inventory was completed in the study area in association with the U.S. Geological Survey. Over 500 wells located within and directly adjacent to the Clark Fork River floodplain were identified and inventoried. Data collected during the inventory included well location, well owner, well completion characteristics, well use, and other pertinent information.

3.2.1.1 Objectives

Objectives to completing the well inventory included the following:

- Determine locations and owners of wells potentially impacted by mine and mill tailings contamination.
- Identify well construction and production characteristics.
- Determine water use of identified wells.
- Provide a preliminary determination of water quality characteristics, based upon field parameters (temperature, pH, and specific electrical conductivity).

The resultant well inventory data base was used to identify a subset of inventoried wells for subsequent groundwater sampling. In addition, the well inventory will provide a basis from which any future remedial investigation/feasibility study activities associated with groundwater can proceed.

3.2.1.2 Changes to the Original Work Plan

No major deviations to the scope of work presented in the original study plan (CH2M HILL, 1987a) resulted during performance of the domestic well inventory. Two facts concerning the well inventory are, however, noteworthy:

- The well inventory was not all inclusive due to the large number of wells within the study area and the fact that many well owners were not home at the time of the site visit.

- All wells were not inventoried in densely populated areas because it was impractical to go house to house given the magnitude of the study area. In these situations, a representative inventory was completed to provide reasonable spatial distribution of inventoried wells in consideration of the range of well depths and completion intervals.

3.2.1.3 Results

The resultant well inventory from completion of this work task is contained in Appendix A. Map 7 (Oversize) shows locations of domestic wells identified in the tabulated well inventory. The following types and numbers of wells are included in the inventory: domestic (438); irrigation (22); stock (19); public supply (22); and unused (37).

Most wells inventoried were completed with six- or eight-inch steel casing, perforated for a few feet near the bottom of the casing or left with an open bottom. Depths of domestic wells inventoried ranged from less than 10 feet to over 400 feet. Most wells are completed either in Clark Fork River alluvium or, more typically, in Tertiary unconsolidated sediments either adjacent to or underlying the alluvial unit. Depths to water in inventoried wells were generally less than 50 feet below ground surface.

3.2.2 Domestic Well Sampling

Domestic wells identified during the well inventory were screened based upon certain criteria to determine those to be sampled for a more complete list of chemical parameters identified in the project study plan (CH2M HILL, 1987a). Screening criteria used to determine domestic wells to be sampled included the following:

- Spatial distribution -- A sampling network capable of providing an assessment of groundwater quality throughout the study area was desired.

- Geology -- Domestic wells were screened based upon the geologic unit in which the wells were completed. Those wells completed in Clark Fork River alluvium were given highest priority. This information was obtained from the well inventory data base.

- Location of wells with respect to exposed tailing deposits -- Wells preferred for water quality sampling were located proximal to exposed tailing deposits. Wells located adjacent to these suspected contaminant sources would have the highest probability of exhibiting degraded water quality characteristics. Wells meeting this criteria were typically located on the floodplain of the Clark Fork River.

- Well depth -- Domestic wells remaining from application of the foregoing screening criteria were next evaluated with respect to the total depth of the wells reported on the well inventory data base. Wells preferred for groundwater sampling were shallow, typically less than 20 feet. This criteria was based upon data collected during the Silver Bow Creek Phase I Remedial Investigation (MultiTech, 1987) which indicated highest metals concentrations occurred in the upper portion of the aquifer.

- Field parameters -- Wells screened from the preceding four criteria were evaluated with respect to field parameter data collected during the well inventory and reported on the well inventory data base (Appendix A). Preference was given to those wells exhibiting relatively low pH values (typically less than 6.5) and/or relatively high specific conductivity values (typically greater than 400 μmhos/cm @ 25° C). In addition, wells exhibiting anomalous field parameter values, but which were excluded from the screening based on previous criteria, were evaluated for inclusion into the sampling program.

- Other factors -- Three other factors were considered in evaluating domestic wells for sampling. These included public water supplies, background wells, and well owner consent. Municipal wells located adjacent to the Clark Fork River were included for sampling because of the number of people serviced by the systems. Several wells located away from the exposed tailing deposits along the Clark Fork River were included for sampling to provide background information for comparative purposes. Consent of well owners was also considered in selecting wells for sampling. This information was obtained from the well inventory field sheets.

3.2.2.1 Objectives

Specific objectives to sampling domestic wells adjacent to the Clark Fork River included the following:

- Provide data to characterize the quality of groundwater resources adjacent to the Clark Fork River spatially throughout the study area.

- Provide sufficient data such that an assessment can be made of public health risks associated with ingestion or use of groundwater derived from aquifers located proximal to the Clark Fork River.

- Provide data to assist in defining operable units within the Clark Fork River screening study area.

3.2.2.2 Changes to the Original Work Plan

No changes to the scope of work presented in the original work plan resulted from completion of the domestic well sampling.

3.2.2.3 Results

Resultant water quality data from the domestic well sampling work task are contained in Appendix B. Map 7 (Oversize) shows locations of domestic wells sampled.

Groundwater quality data indicate several exceedances of primary and secondary maximum contaminant levels (MCLs and SMCLs) for domestic wells sampled. These exceedances are identified in Table 3-1. Locations of those domestic wells exceeding MCLs and SMCLs, shown generally on Figure 3-2, appear to be relatively random, although five of the wells exhibiting exceedances were located in the vicinity of Garrison Junction.

Other collected data indicate groundwater within the study area is typically a calcium or sodium bicarbonate type, exhibiting average specific conductivities of approximately 480 μmhos/cm @ 25° C and near neutral pH values. The data indicate most metals parameters measured were near or below method detection limits.

3.2.3 Monitoring Well Construction and Sampling

Ten monitoring wells were constructed in the Clark Fork River alluvial aquifer in areas exhibiting exposed or buried mine and mill tailing deposits. Criteria used to select locations for monitoring well installations included the following:

- Sites must have been identifiable on LANDSAT imagery as exhibiting high iron band resolution.

- Sites chosen must provide adequate spatial distribution to characterize water quality in the shallow alluvial aquifer in areas exhibiting exposed tailing deposits.

- Access permission must be obtainable from land owners.

TABLE 3-1

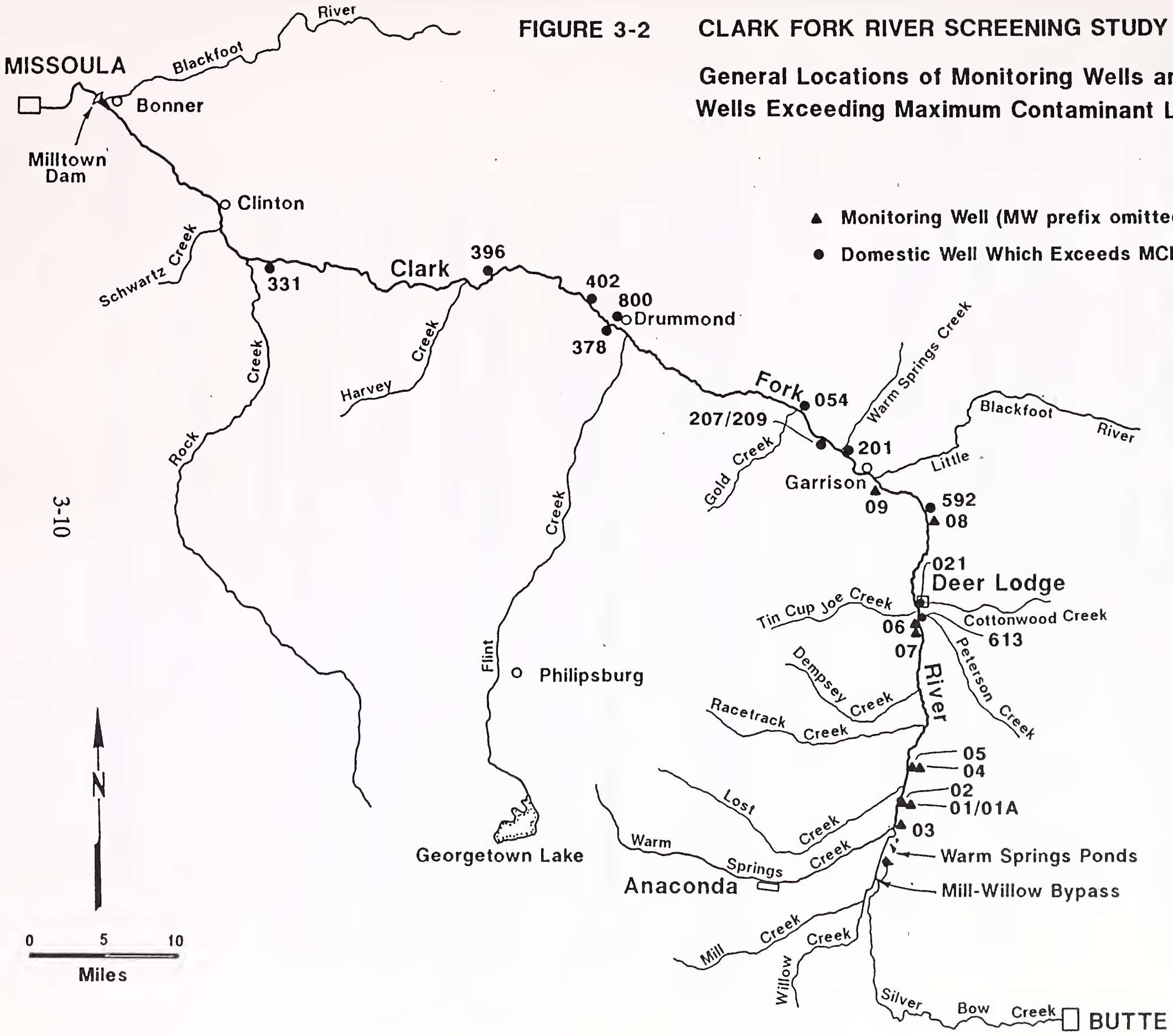
MAXIMUM CONTAMINANT LEVEL EXCEEDANCES IN DOMESTIC WELLS, CLARK FORK RIVER SCREENING STUDY

	Well No.	Concentration	General Location
Primary Standard			
Cadmium (10 μg/L)	DW-592	14 μg/L	6 Miles North of Deer Lodge
Secondary Standard			
Iron (300 μg/L)	DW-021	490 μg/L	Deer Lodge
	DW-402	5100 μg/L	Northwest of Drummond
	DW-396	470 μg/L	Near Bearmouth
	DW-331	460 μg/L	East of Rock Creek
	DW-800	910 μg/L	West end of Drummond
	DW-054	410 μg/L	Near Gold Creek
	DW-209	330 μg/L	4 Miles Northwest of Garrison
	DW-201	4900 μg/L	2 Miles Northwest of Garrison
	DW-613	2450 μg/L	1 Mile South of Deer Lodge
	DW-207	420 μg/L	4 Miles Northwest of Garrison
Manganese (50 μg/L)	DW-402	490 μg/L	Northwest of Drummond
	DW-378	390 μg/L	1 Mile Southwest of Drummond
	DW-054	1150 μg/L	Near Gold Creek
	DW-201	1430 μg/L	2 Miles Northwest of Garrison
Sulfate (250 mg/L)	DW-402	364 mg/L	Northwest of Drummond
	DW-396	368 mg/L	Near Bearmouth
	DW-378	346 mg/L	1 Mile Southwest of Drummond

Well locations shown on Figure 3-2 and Map 7 (oversize)

FIGURE 3-2 CLARK FORK RIVER SCREENING STUDY

General Locations of Monitoring Wells and Domestic Wells Exceeding Maximum Contaminant Levels



Monitoring wells were installed at selected sites with an auger drill rig. Lithologic logs were generated during drilling activities associated with monitoring well construction. Following well installation, wells were developed to insure hydraulic communication between the wells and the adjacent aquifers. Wells were subsequently sampled for chemical parameters described in the project FOP and QAPP (CH2M HILL, 1987c, 1987e).

Monthly water level data were collected for a period of six months following well construction. In addition, three staff gages were installed in the Clark Fork River adjacent to several of the installed monitoring wells such that comparisons between river stage and groundwater elevations could be made. A survey was completed at each of the three staff gage sites to correlate elevations between river stage and groundwater elevations in adjacent monitoring wells.

3.2.3.1 Objectives

Objectives to constructing and sampling monitoring wells and to obtaining monthly water level measurements included the following:

- Provide data to describe groundwater quality directly beneath exposed and buried tailings deposits in the Clark Fork River floodplain spatially.
- Provide information on the lithology of the shallow alluvial aquifer present adjacent to the Clark Fork River.
- Provide data on the influent-effluent characteristics of the Clark Fork River.
- Provide data to aid in identifying operable units in the study area for the Clark Fork River screening study.

3.2.3.2 Changes to the Original Work Plan

No changes resulted to the original work plan from completion of this work task.

3.2.3.3 Results

Lithologic and well completion logs resulting from monitoring well installation activities are contained in Appendix C. Locations of installed monitoring wells are shown on Figure 3-2 and Map 7 (Oversize). Monitoring well development logs are contained in Appendix D. Water quality data resulting from monitoring well sampling are contained in Appendix E. Water level data from monitoring wells and staff gages are presented in Table 3-2 and are illustrated in Figures 3-3 through 3-8.

Data collected during monitoring well installation activities indicated shallow lithologies generally consisted of one to four feet of light tan to orange tailings overlying a two to three foot thick dark brown to black silt exhibiting numerous root and wood fragments. A medium-grained sand or poorly sorted gravel typically was present subjacent to the silt unit. Water was generally encountered near the top of this lower coarse grained unit.

Groundwater quality data from installed monitoring wells (Appendix E) indicate primary and secondary MCLs in drinking water were exceeded in several of the monitoring wells sampled. Table 3-3 summarizes measured exceedances.

Metals in the shallow groundwater system adjacent to the Clark Fork River in the Deer Lodge Valley downgradient of Warm Springs are elevated with respect to concentrations measured in the shallow groundwater system south of the Warm Springs Ponds reported in CH2M HILL (1989) and as compared to domestic wells completed in deeper water-bearing units within the study area. Samples obtained from cross valley monitoring wells near Perkins Lane Bridge, north of the Warm Springs Ponds, and near the Galen Bridge indicate groundwater quality generally improves toward the river. This may indicate tailing deposits located on the first and second terraces of the Clark Fork River are sources for localized groundwater contamination.

Groundwater level data collected from monitoring wells installed adjacent to the Clark Fork River and from staff gages installed in the Clark Fork River indicate seasonal changes in groundwater levels and in staff gage elevations during the period of data collection (Figures

TABLE 3-2

MONITORING WELL STATIC WATER LEVEL DATA, CLARK FORK RIVER SCREENING STUDY
(DEPTH TO WATER BELOW MEASURING POINT (ft.))

WELL/STAFF NO.	DATE									
	07/15/87	07/21/87	07/28/87	08/21/87	09/22/87	10/21/87	11/24/87	12/21/87	02/22/88	05/25/88
CFR-MW-01	3.65	3.03	3.25	3.70	3.50	3.97	4.32	4.88	5.52	4.18
CFR-MW-01A	6.66	3.55	3.70	4.15	3.95	4.25	4.81	5.35	6.00	4.34
CFR-MW-03	3.52	3.12	3.78	3.65	3.85	3.97	4.18	4.86	4.72	3.55
STAFF			0.01	-0.80	-0.95	-1.00	0.17	0.20		1.23
CFR-MW-03	3.65	4.04	4.43	3.45	3.95	3.97	4.16	4.44	3.93	3.45
CFR-MW-04	3.85	3.84	3.78	4.00	3.85	3.43	3.50	3.84	4.72	3.43
CFR-MW-05	4.00	3.93	4.40	4.50	4.47	3.45	4.42	4.19	4.45	3.70
STAFF			0.32	0.24	0.24	0.24	0.36	0.60	0.27	1.07
CFR-MW-06	4.60	5.52	5.39	5.60	5.39	5.25	5.13	5.18	5.15	4.86
CFR-MW-07	3.75	4.23	4.57	4.80	4.40	4.27	4.25	4.26	4.45	4.35
STAFF			0.21	0.24	0.24	0.42	0.56	0.46	0.45	0.79
CFR-MW-08	4.00	3.50	3.97	4.37	4.07	4.00	4.02	3.85	3.12	3.77
CFR-MW-09	4.70	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY

Well locations shown on Figure 3-2 and Map 7 (Oversize)

FIGURE 3-3 GROUNDWATER AND STAFF GAGE ELEVATIONS NEAR PERKINS LANE BRIDGE; CLARK FORK RIVER SITE ASSESSMENT

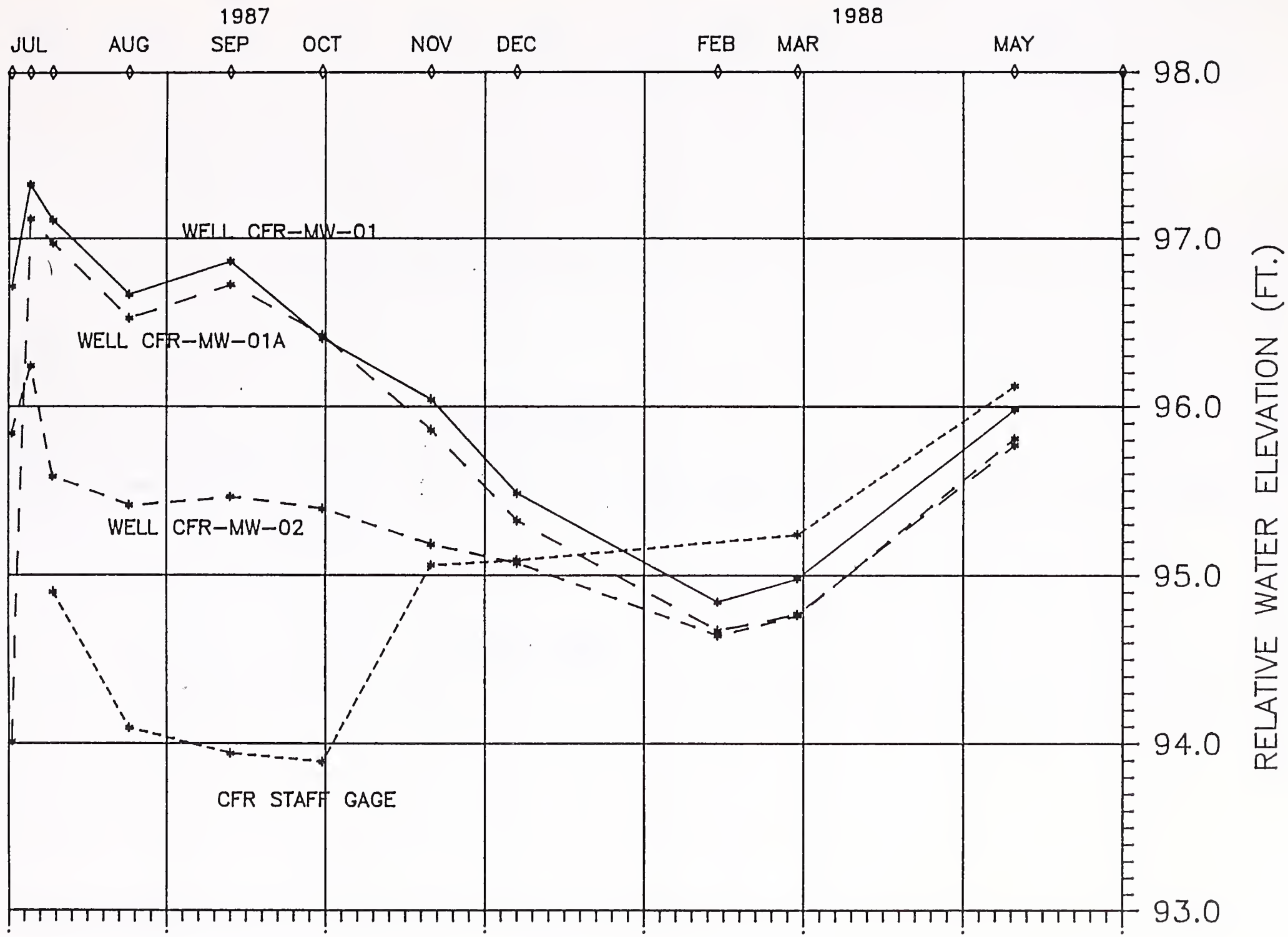


FIGURE 3-4 GROUNDWATER AND STAFF GAGE ELEVATIONS NEAR GALEN BRIDGE; CLARK FORK RIVER SITE ASSESSMENT

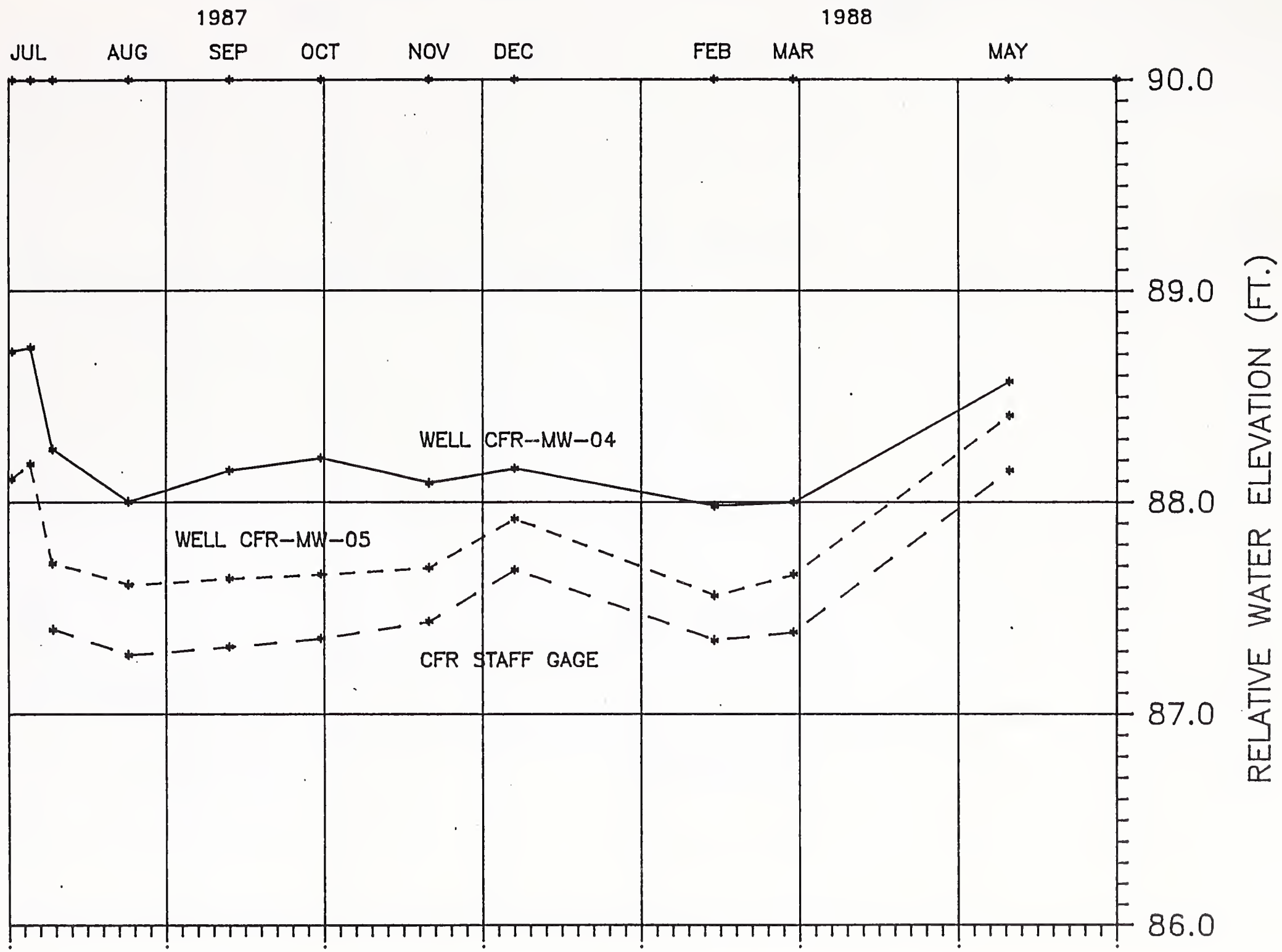


FIGURE 3-5 GROUNDWATER LEVEL AND STAFF GAGE ELEVATIONS NEAR DEER LODGE; CLARK FORK RIVER SITE ASSESSMENT

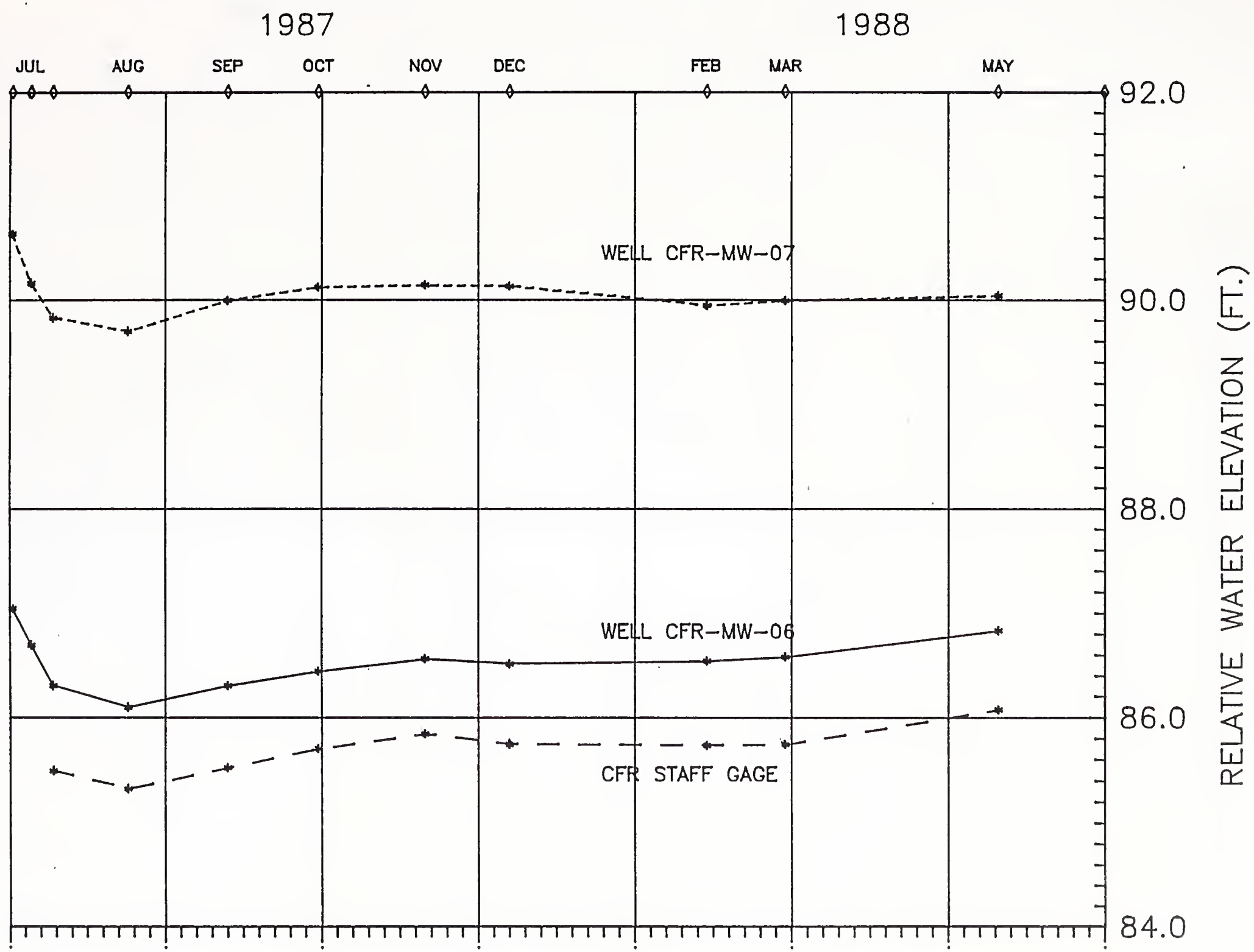


FIGURE 3-6 GROUNDWATER ELEVATIONS AT MONITORING WELL CFR-MW-03

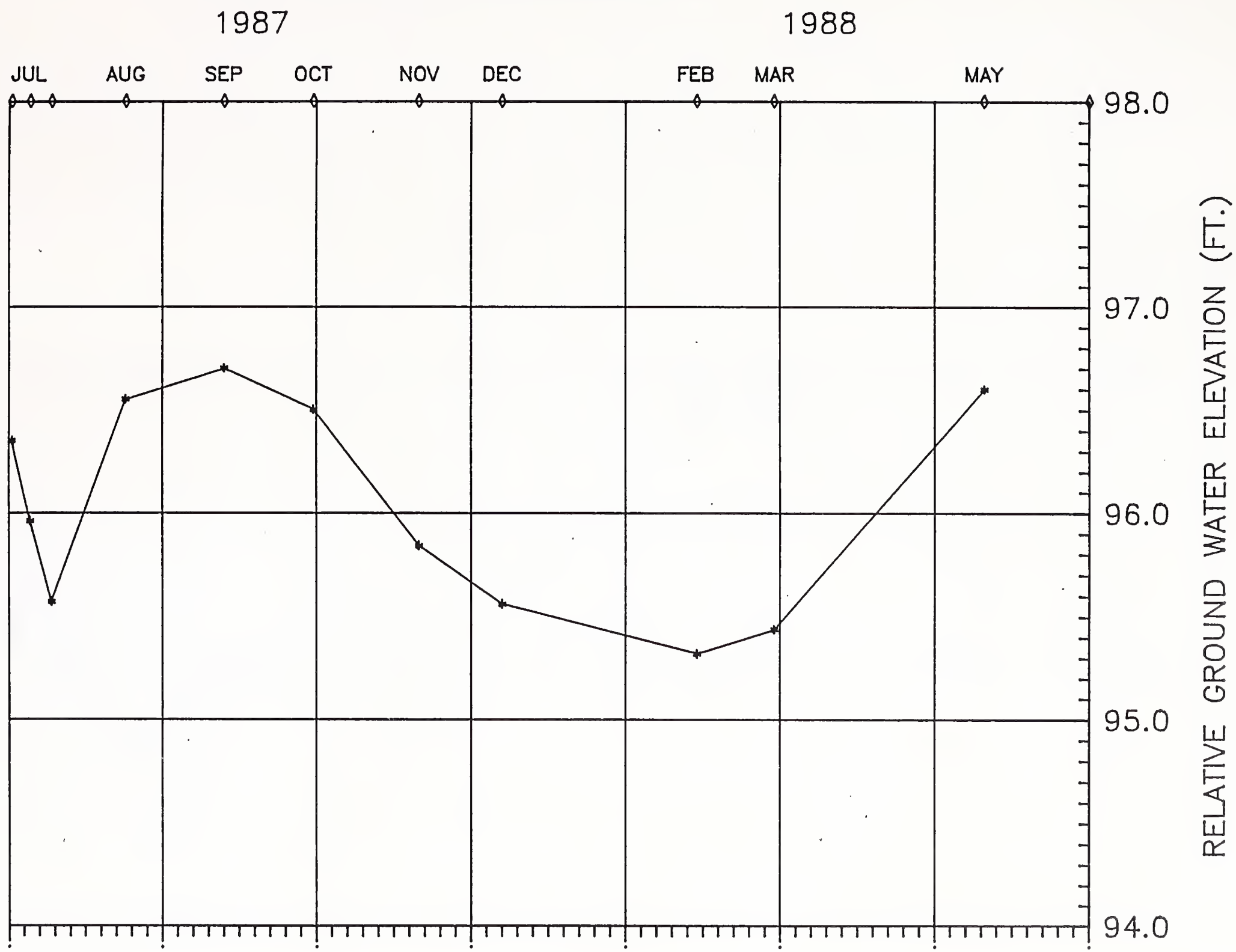


FIGURE 3-7 GROUNDWATER ELEVATIONS AT MONITORING WELL CFR-MW-08
CLARK FORK RIVER SITE ASSESSMENT

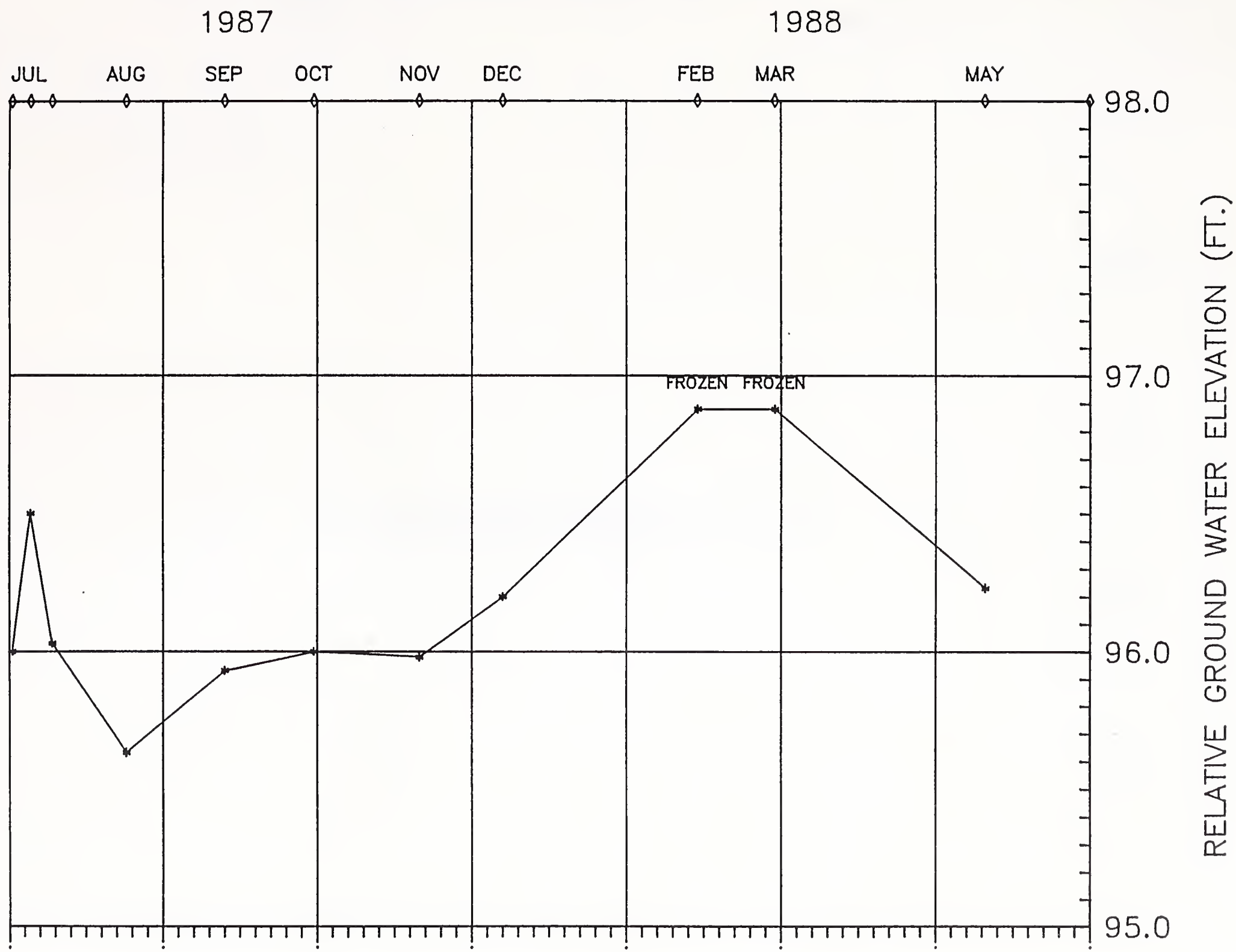


FIGURE 3-8 GROUNDWATER ELEVATIONS AT MONITORING WELL CFR-MW-09
CLARK FORK RIVER SITE ASSESSMENT

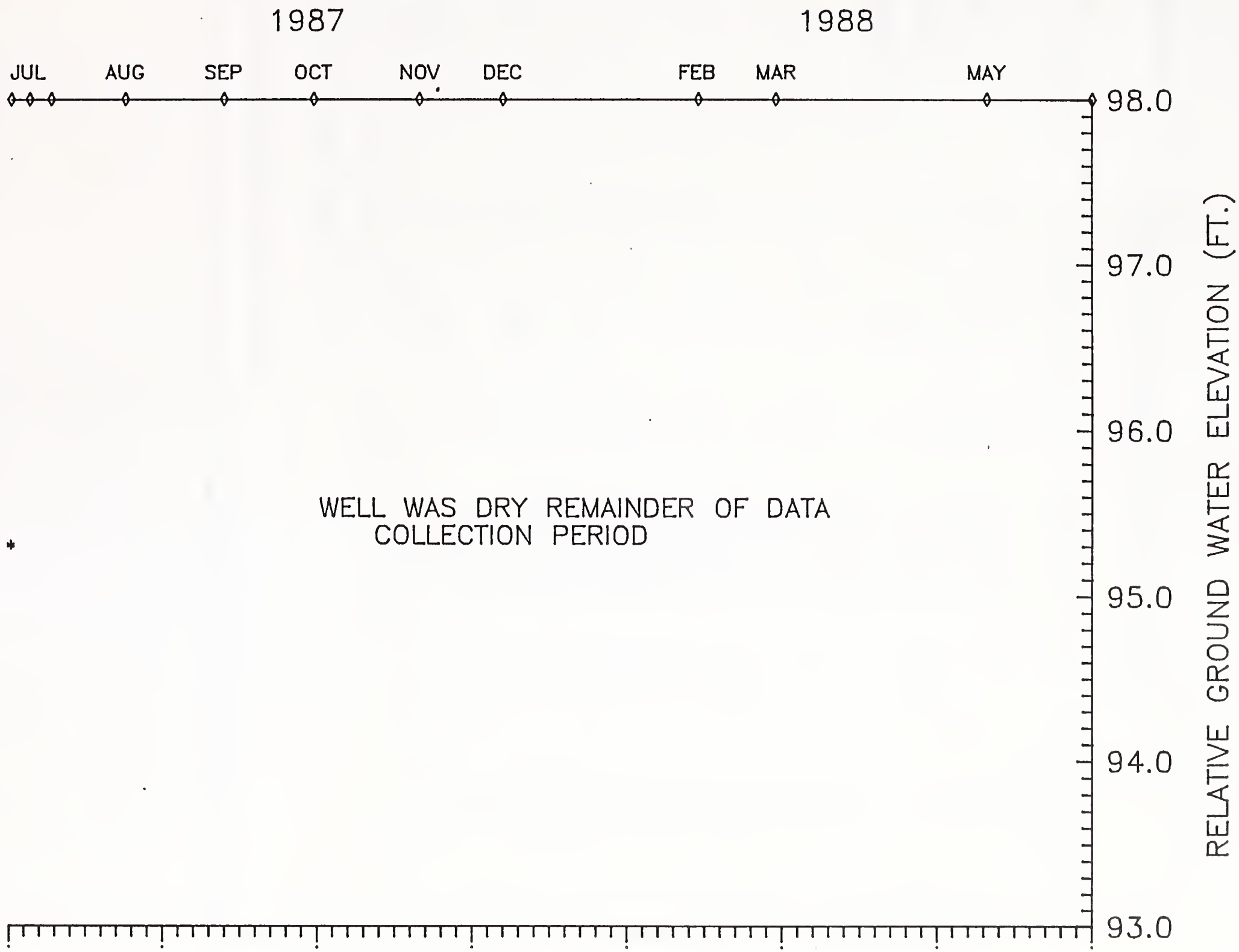


TABLE 3-3

MAXIMUM CONTAMINANT LEVEL EXCEEDANCES IN MONITORING WELLS, CLARK FORK RIVER SCREENING STUDY

Parameter	MCL (μg/L)	Well No.[1]	Concentration (μg/L)
Arsenic[2]	50	MW-04	170
Cadmium[2]	10	MW-04	11
Manganese[3]	50	MW-01	210
		MW-01A	820
		MW-08	170
		MW-03	1080
		MW-04	130
		MW-05	190
		MW-06	80
		MW-08	2870
Iron[3]	300	MW-02	820
		MW-08	320
Sulfate[3]	250000	MW-04	344000

[1] Well Locations Shown on Figure 3-2 and Map 7 (oversize)

[2] Primary Drinking Water Standard

[3] Secondary Drinking Water Standard

3-3 through 3-8). Lowest elevations generally occurred during winter months except at Deer Lodge where lowest groundwater and staff gage elevations occurred during late summer (Figure 3-5).

Direction of groundwater movement was from the shallow alluvial groundwater system to the Clark Fork River at stations located at Galen Bridge and near Deer Lodge throughout the period of record (Figures 3-4 and 3-5). Elevations of groundwater and surface water tracked closely at both of these sites. Data collected from near Perkins Lane Bridge (Figure 3-3), however, indicated a gradient reversal occurred in December, 1987 wherein the Clark Fork stage raised to an elevation higher than the adjacent alluvial groundwater system. Losing stream conditions continued at the Perkins Lane Bridge site through spring-time measurements.

3.3 SOILS AND VEGETATION FIELD INVESTIGATION

The soils and vegetation investigation completed for the Clark Fork River screening study was to include two primary components. These included a contaminated soils and vegetation field investigation (ground survey and sampling) and an analysis of soils and vegetation within the study area by remote sensing techniques. This section of the report describes the former investigation only.

Several work tasks were performed during the contaminated soils and vegetation field investigation. These included:

- Selection of candidate study sites using LANDSAT and low altitude photographs, other tailings maps, and historical data.

- Ground-truthing candidate sites, selecting those that met specific criteria. (Criteria are listed in Table 3-4).

- Describing each sampling site.

TABLE 3-4

DEFINITION CRITERIA FOR SITE TYPES
CLARK FORK RIVER SCREENING STUDY

Site Type	Definition Criteria
Bare Tailings	Low level aerial photographs showing tailings material on the surface and moderate to low vegetation cover; high metal reflectance on LANDSAT photographs.
Buried Tailings	No tailings material visible on surface; located adjacent to Clark Fork River; low to high metal reflectance on LANDSAT photographs.
Good Plant Growth	Hayfields that were never irrigated with Clark Fork River water and have good to excellent production; low metal reflectance on LANDSAT photographs.
Historically Irrigated	Areas that have been irrigated with Clark Fork River water; moderate to high metal reflectance on LANDSAT photographs.

- Collecting extensive X-ray fluorescence spectrometer (XRF) data and corresponding soil samples at each site.

- Collecting vegetation data necessary to characterize the composition, canopy coverage and production for each site.

- Evaluating XRF data in terms of hazard criteria levels.

- Comparing and contrasting each site in terms of soils and vegetation data.

- Compiling and summarizing all field observations and collected field data.

3.3.1 Objectives

The primary objectives of the contaminated soils portion of the Clark Fork River screening study were to:

- Determine the magnitude of contamination at sites representative of the degree of contamination present within the study area.

- Correlate XRF values with laboratory determined concentrations for target elements.

- Determine if XRF can accurately identify areas where soil metal concentrations exceed hazard criteria levels.

- Correlate these data to remote sensing data and other project data bases and maps.

3.3.2 Methods and Procedures

Because the scope of work outlined in the project study plan for the contaminated soils investigations (CH2M HILL, 1987d) was necessarily written to allow for flexibility based upon field conditions, this section is presented to document methodologies and procedures used during this portion of the soils investigation along the Clark Fork River.

3.3.2.1 Site Selection and Locations

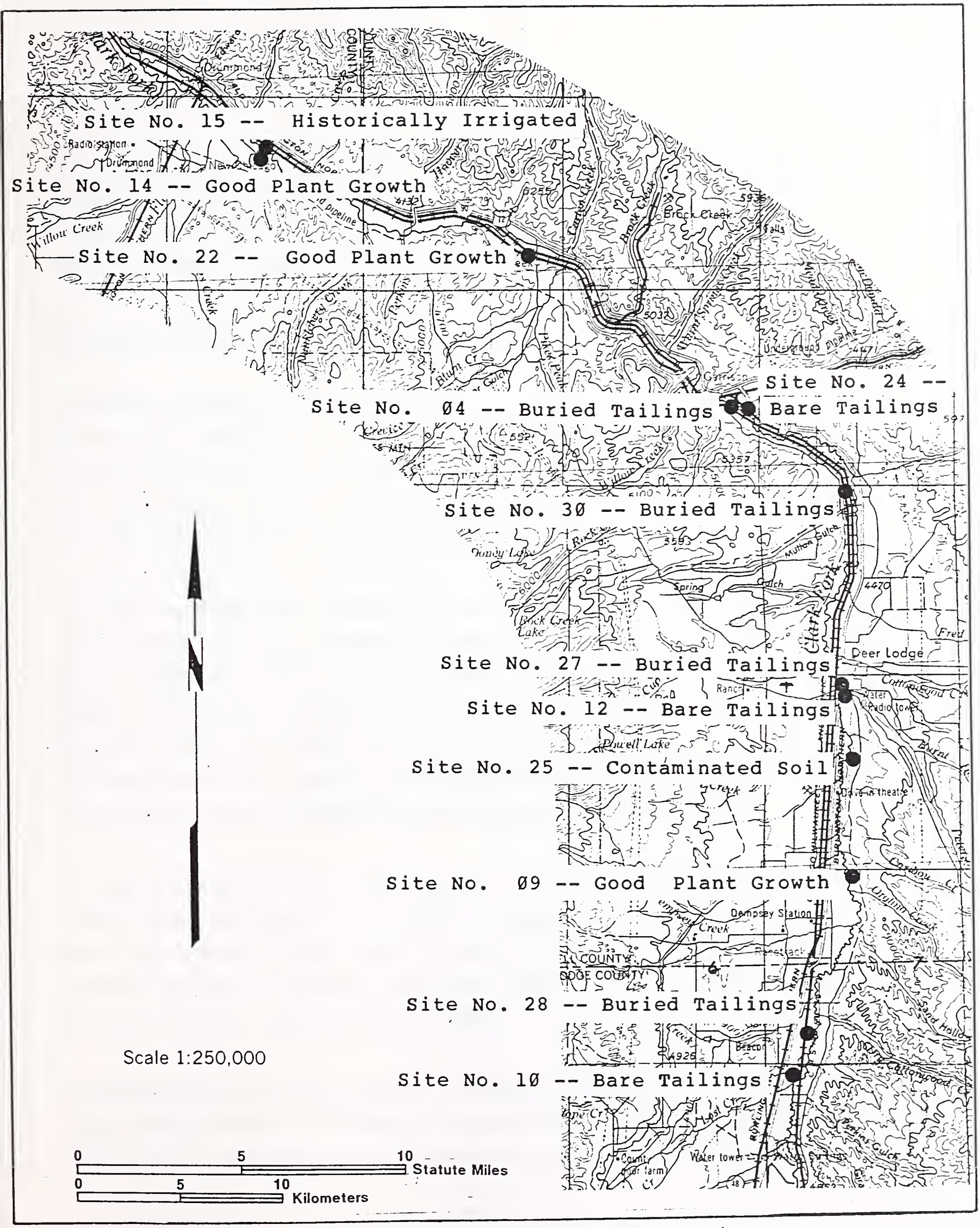
To accomplish task objectives described above, four types of sites, representing various degrees and locations of environmental contamination in the study area, were defined (Table 3-4). Prior to selecting potential sites for field investigation, LANDSAT satellite photographs of the study area were reviewed with respect to spectral reflectivity. In addition, low level color aerial photographs and maps of the study area were reviewed. This process resulted in the selection of 25 candidate sites located between Warm Springs and Milltown.

Each candidate site was evaluated in the field as to whether it met the criteria for a particular site type (Table 3-4). If a site did not match the specified criteria, it was not sampled and another site was evaluated. This iterative process continued until a total of 12 sites were selected for sampling.

The final 12 sites were located adjacent to the Clark Fork River between the towns of Warm Springs and Drummond, Montana (Figure 3-9) (Map 7, Oversize). Specific site locations and directions to each site are contained in Appendix F.

3.3.2.2 Data Collection

The following types of data were collected at each of the 12 sites selected for detailed analysis.



CLARK FORK RIVER SITE SCREENING STUDY AREA
General Location of Sampling Sites, CFRSS

FIGURE 3-9

Site Descriptions

Site descriptions included a narrative text identifying features such as geomorphic setting, dominant soils, landform, aspect, degree and extent of contamination, noticeable effects on vegetation, proximity to the Clark Fork River channel, vegetation type, productivity, and current and past land uses. This information is presented by site in Section 3.3.4.

XRF Data and Tailings/Soil Sampling

At each site, sampling stations for the collection of XRF data were established on a 100 foot (30 m) grid. The goal was to sample an area greater than five but less than 10 acres (between two and four hectares (ha)). In some cases, the site satisfied the selection criteria but was less than the five acre (two ha) minimum. Depending on the size of the site, between 30 and 55 gridded sampling stations were established.

The XRF spectrometer was calibrated at least daily using a soil sample containing known concentrations of the target elements. At each station, tailings/soil material was exposed to the XRF instrument for 30 seconds. Index and count XRF values for arsenic (As), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) were then recorded. Often XRF readings were taken at multiple depths, which resulted in as many as 60 readings per site. Once the entire site had been examined using XRF, 20 stations were selected from which laboratory destined samples would be collected.

The goal for selecting stations at which laboratory samples would be collected was two-fold: first, to select stations that were relatively evenly spaced throughout the site and second, to select stations that had target element concentrations representative of the full range of values for that site. These 20 samples were used to correlate XRF index values to laboratory determined element concentrations.

At each of these 20 "correlation" stations, a tailings/soil sample was obtained from a specific depth within the profile. Each individual sample was thoroughly mixed by rolling it on a plastic tarp. A sub-sample of each collected and mixed sample was exposed to the XRF

spectrometer for 100 seconds and the index and count values for the target elements were recorded. Another sub-sample of this material was packaged in accordance with EPA CLP requirements for subsequent shipment to the contract laboratory for determination of total concentrations of As, cadmium (Cd), Cu, Fe, Pb, Mn, selenium (Se), mercury (Hg), and Zn.

In addition, pH and electrical conductivity (EC) measurements of saturated soil paste extracts of these samples were determined by the contract laboratory. These data are presented for each site in Appendix G.

Vegetation Data Collection

Concurrent with the collection of XRF data, vegetation maps were drawn and the canopy coverage of each plant species was recorded. Using the flagged grid as a guide, a map was drawn showing important morphological features of the site. These included the vegetation association, the patterns of surface tailings/soil, and cultural features such as roads, fences and ditches.

Species specific canopy coverage and the amount of bare ground were estimated at each station. This was accomplished by placing a 20 X 50 cm frame on the ground and recording the percent of the frame covered by each plant species. Average plant production was estimated in the field. Unknown plant species were collected for later identification and verification with known specimens. Several photographs, both aspect and close-ups, were taken at each site.

3.3.2.3 Data Reduction and Summarization

All field observations and measurements were compiled. Field XRF data and laboratory determined total element concentration data were entered into dBase III+ files and verified. Index XRF values and laboratory derived concentration data for the target elements were evaluated and preliminary regression analyses were completed. It was determined that linear correlation models could be used for five of the six target elements; these included As, Cu, Fe, Pb and Zn. Spectral interference prevented the correlation of Mn. Linear

regression analyses were performed using Statistical Analytical Services (SAS) software for each of the target elements where both XRF index values and laboratory derived total concentrations were available. These regression statistics were then used to calculate element concentrations (dependent variable) from the XRF index values (independent variable) for each sampling station.

Vegetation data were collected for each site with the ultimate goal of providing objective plant species cover data to describe the plant community at each site. Daubenmire frames (20 x 50 cm) were randomly placed in undisturbed vegetation adjacent to most XRF sampling stations. Canopy coverage or the percent of the ground within the frame covered by a vertical projection of the extremities of the plant canopy was determined for each species at each station. Since vegetation canopies may overlap, total plant cover may exceed 100 percent. When plant coverage is less than 100 percent, the total of plant coverage and bare ground may exceed 100% because of the presence of vegetation in several overlapping canopies. Means of plant coverage were calculated for each plant species at each site. The percent composition (species canopy cover/total canopy cover x 100) or the relative canopy coverage of each species was also calculated (see Tables in this Section).

The vegetation cover data are presented to represent the composition of the plants on the site and may be extrapolated to the entire site. Nevertheless, the reader must be cognizant of the spacial distribution of the plants in unique communities across the site and realize that the site is not a uniform mixture of the species listed (See Appendix H for site maps).

Because this vegetation study was carried out only to characterize the dominant vegetation and to document the amount of bare ground at each site, no notation of dead plant cover (litter) was made. Litter cover is equal to ground covered by dead plants. Therefore, the sum of total plant cover and bare ground may not equal to 100 percent. At those sites at which this occurs, the discrepancy is the presence of plant litter on the site.

3.3.3 Changes to the Original Study Plan

The following are changes to the original study plan (CH2M HILL, 1987a) which resulted from completion of the contaminated soils field investigation:

- Several study sites initially selected during early meetings of study team members were rejected in the field as not being representative of study area conditions or as not meeting certain predetermined selection criteria. Field decisions were then necessary to choose and evaluate alternative sites.

- Hand-dug soil excavations to the 30 inch (76 cm) depth to obtain soil horizon descriptions and morphological data were not performed because of the excessive amount of time needed to execute this task. Subsurface soil/tailings samples were taken to evaluate contamination.

3.3.4 Results and Discussion

Results of the contaminated soils field investigation are discussed by site type (i.e. Bare Tailings, Buried Tailings, Good Plant Growth, or Historically Irrigated). Bare Tailings sites were classified as such by having a preponderance of tailings material on the surface of the ground. These sites were located within the active floodplain of the Clark Fork River. Buried Tailings sites were also located within the active floodplain but tailings materials were not visually apparent. Close examination of the soil profiles at these sites revealed buried layers of tailings materials or, more commonly, tailings mixed with soil or alluvial material. Sites classified as Good Plant Growth sites were hayfields in which production exceeded 1800 lb/A (2018 kg/ha). These sites had never been exposed to water from the Clark Fork River, neither through natural flooding nor from agricultural irrigation. Historically Irrigated sites were those that had been irrigated with water from the Clark Fork River and therefore potentially had elevated levels of the target elements.

Total element concentrations are presented relative to background and phytotoxic levels (Table 3-5). Background values were obtained from sites that were assumed to be free of

TABLE 3-5.

BACKGROUND AND PHYTOTOXIC CONCENTRATIONS (μg/g - DRY WEIGHT) FOR SELECTED ELEMENTS IN SOIL MATERIALS

	- - - - - - - - - - Selected Elements - - - - - - - - - -								
	As	Cd	Cu	Fe	Pb	Mn	Hg	Se	Zn
Reference	Background Concentrations								
U.S. Mean soil (Kabata - Pendias and Pendias 1984)	6.7	.73	24.0	---	20.0	495	.09	.3	58.0
U.S. Mean soil (Adriano 1986)	7.2	.30	29.0	---	15.0	560	.09	.1-2	65.0
Helena Valley Mean soil (EPA 1987a)	16.5	.24	16.3	15248	11.6	336	.08	.07	46.9
Missoula Lake bed sediments (Moore 1985)	--	.20	25.0	---	34.0	406	---	---	105.0
Blackfoot River sediments (Rice and Ray 1985)	4.0	<.1	13.0	---	---	---	---	---	---
Site 14 Mean soil (CFRSS) (This investigation)	16.0	.76	29.0	19270	15.0	514	.08	<.35	82.0
	Phytotoxic Concentration								
Soils (EPA 1986 and 1987b)	100.0	100.0	100.0	---	1000.0	---	5.0	10.0	500.0

anthropogenic contamination. Background levels used in this study were mean element concentrations from Site 14. These values were similar to background values obtained from throughout the United States (Kabata-Pendais and Pendais, 1984; Adriano, 1986) and values obtained from background sites in Montana (EPA, 1987b; Moore 1985, Rice and Ray, 1984).

Phytotoxic soil concentration levels were obtained from two EPA sponsored literature reviews (EPA, 1986, 1987a). These documents summarized research regarding the effects of certain elements on plant growth. The phytotoxic level was defined as the level at which physiological plant stress occurred. Some plant yield reduction would be expected at soil concentrations at or above the phytotoxic levels. It is noteworthy that these hazard levels are only an approximation. A plant's element tolerance depends upon many factors including: the plant ecotype, soil chemical factors such as pH, EC, and the concentration of other elements, soil mineralogy, and the influence of climate.

Vegetation statistics and linear regression summaries for the correlation between field XRF index values and laboratory determined total concentrations for the target elements are presented for each site in the sections that follow.

The accuracy of using the XRF spectrometer to determine phytotoxic levels of the target elements within the Clark Fork River study site was evaluated. This was accomplished by comparing laboratory determined element concentrations to calculated element concentrations for each sample. Calculated values were obtained using the field XRF index values and the regression equation for that particular element. A detailed description of the XRF evaluation is provided in the beginning of Section 3.3.4.1 and Appendix I.

Presented in Appendix H are maps outlining the sampling scheme for each site. Each map has a coordinate system for identifying an individual sampling station and for locating data pertinent to that station.

Tables in Appendix I provide detailed data listings for the target elements at each sampling station within each site. These tables include the following parameters: station coordinates, depth sampled, EPA tag number, XRF index values, laboratory determined element

concentrations, and calculated concentrations, standard deviations and 95 percent confidence intervals using the regression model. Appendix J contains field forms developed in collecting XRF data at the various study sites. Appendix K summarizes the Quality Assurance/Quality Control reports for all environmental samples collected during this study.

3.3.4.1 Bare Tailings Sites

Site No. 10

Site No. 10 is located about 2.5 miles (4.0 km) north of the town of Warm Springs. The site consists of approximately 11 acres (4.5 ha) located within an oxbow of the Clark Fork River (Map 7, Oversize). The site is located immediately adjacent to the river and extends northward from the river approximately 700 feet (213 m) (Appendix F). Site 10 is within the lowest floodplain level and contained tailings-filled overflow channels and old oxbows. Tailing deposits were at least two feet (0.6 m) thick and were underlain by Quaternary alluvial material. The site was at an elevation of approximately 4755 feet (1450 m).

Table 3-6 lists laboratory determined mean concentrations, ranges and standard deviations for the target elements at Site 10. The number and percentage of laboratory values that were below background and above phytotoxic levels are also presented. The performance of the XRF spectrometer was evaluated by comparing the laboratory determined concentration to the calculated value for each sample. Calculated values were obtained using field XRF index values and the regression equation for that particular element. The raw data used to generate these statistics are listed in Appendix I.

A criterion used to evaluate the performance of the XRF was determining whether the calculated value was consistent with the laboratory value in terms of the phytotoxic level. A "correct calculation of phytotoxic or non-phytotoxicity" occurred when both the laboratory and the calculated values were either above or below the phytotoxic level. When the calculated and the laboratory values were inconsistent, in terms of the phytotoxic level, then it was deemed an incorrect calculation. For example, all calculated As values (20 out of 20, 100%) were consistent with the laboratory determined concentrations in terms of the

TABLE 3-6
STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 10

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		598	2752	21500	1576	442
Minimum-Maximum		210-1770	710-6140	8200-44200	400-3160	217-1030
Standard Deviation		403	1734	10638	939	217
Below Background	n	0	0	11	0	0
	%	0	0	55	0	0
Above Phytotoxic	n	20	20	NK	18	1
	%	100	100	--	90	5
Calculated Values (n=20)[4]						
Above Phytotoxic	n	20	20	NK	20	0
	%	100	100	--	100	0
Correct calculation of phytotoxicity or non-phytotoxicity.	n	20	20	NK	18	19
	%	100	100	--	90	95
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	12	15	NK	4	18
	%	60	75	--	20	90
Correlation Coefficient[5]		0.9165*	0.9252*	0.8908*	0.7073*	0.7282*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

phytotoxic level (Table 3-6). In this case, all 20 samples had both laboratory and calculated concentrations that were above the phytotoxic level of 100 μg/g (see Table 3-5 for background data).

Calculated values were then evaluated with respect to the 95 percent confidence interval. A "correct calculation of phytotoxicity or non-phytotoxicity at the 95 percent confidence level" occurred when the confidence interval of the calculated value was either above or below the phytotoxic level. Listed in Table 3-6 are the number (and percent) of samples for which a 95 percent confidence level was calculated correctly. As an example, for As we are 95 percent confident that 12 out of 20 samples (60%) were correctly calculated (Table 3-6).

Mean element concentrations exceeded phytotoxic criteria for As (598 μg/g), Cu (2752 μg/g) and Zn (1576 μg/g) at Site No. 10 (Tables 3-6 and 3-5). All samples had As and Cu laboratory determined total concentrations that were above the 100 μg/g phytotoxic level. For Zn, 90 percent of the samples were above the 500 μg/g phytotoxic level, but only one sample (5%) exceeded the phytotoxic level (1000 μg/g) of Pb. Phytotoxic criteria for Fe have not been established so no statistics are presented. The number and percent of samples below the Fe background concentration (19270 μg/g from Site 14) is listed.

In terms of phytotoxic levels, calculated values were similar to the laboratory values. All 20 samples were calculated as phytotoxic for As, Cu and Zn, while no samples were calculated phytotoxic for Pb. This was expected since laboratory concentrations of As, Cu and Zn were generally much greater than the phytotoxic levels and the laboratory values of Pb were generally much lower than the phytotoxic level. Correct calculations of phytotoxicity or non-phytotoxicity were greater than 90 percent for all elements. This indicated that the XRF spectrometer accurately assessed this site in terms of As, Cu, Zn, and Pb phytotoxicity. We are 95 percent confident that 60, 75, 20 and 90 percent of the calculated values of As, Cu, Zn, and Pb, respectively, are correct.

Correlation coefficients for the target elements were significant ($P \leq .05$)*, which also indicated a high degree of accuracy in using XRF to determine the concentration of these elements at this site. Values ranged from 0.707 for Zn to 0.926 for Cu (Table 3-6).

Approximately 62 percent of the site was devoid of living vegetation (Table 3-7). Total canopy coverage for this living vegetation was 35.6 percent. There was also some litter on the site. Grasses and grass-like plants dominated the site, accounting for about 73 percent of the total plant canopy coverage (i.e. 73% composition). Dominant grasses were redtop and tufted hairgrass. Shrubs, the next most dominant plant class, had a total composition of 25.6 percent; willow was the major shrub species, but Wood's rose was also present. Forbs were rarely encountered and had only about one percent of the total composition. Total vegetation production was estimated to be about 200 lb/A (224 kg/ha), substantially less than the 1800 lb/A (2018 kg/ha) average for native rangeland (USDA 1982). The site had many dead shrubs and trees, indicating that it had been productive at one time but had since deteriorated.

Site No. 12

Site 12 was located approximately 1.0 mile (1.6 km) south of Deer Lodge, just east of interstate 90 (Map 7, Oversize). The site consisted of about 12 acres (4.9 ha) and, like Site 10 appeared as a mosaic of barren tailings and sparse vegetation. This site was located on a low bench about 300 feet (92 m) east of the Clark Fork River at an elevation of approximately 4530 feet (1381 m). The area was dissected by active shallow overflow channels and was covered by about 1.25 feet (0.4 m) of tailings materials, which was in turn underlain by alluvial gravel.

Like Site 10, mean element concentrations were also high; mean levels of As, Cu, Zn and Pb were 432, 7317, 2406 and 446 μg/g, respectively (Table 3-8). Arsenic, Cu, and Zn had mean concentrations that exceeded phytotoxic criteria. Copper and Zn concentrations were generally higher at this site than at Site 10.

* Probability is 5% or less that the correlation could occur by chance.

TABLE 3-7

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION
ON SITE 10 -- BARE TAILINGS, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Agrostis alba	Redtop	16.6	46.6
Deschampsia caespitosa	Tufted hairgrass	7.9	22.2
Juncus balticus	Baltic rush	[illegible].6	4.5
		26.1	73.3
Forbs			
Traxacum officinale	Dandelion	0.2	0.6
Solidago missouriensis	Missouri goldenweed	0.1	0.3
Unidentified Forbs		0.1	0.3
		0.4	1.1
Shrubs			
Salix species	Willow	8.5	23.9
Rosa woodsii	Wood's rose	0.6	1.7
		9.1	25.6
	TOTALS	35.6	100.0
Total Bare Ground = 61.5%			

TABLE 3-8.

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS ($\mu g/g$), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 12.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		432	7317	18370	2406	446
Minimum-Maximum		24-1100	96-87100	11600-29600	515-13300	18-1330
Standard Deviation		267	18930	5552	2881	320
Below Background	n	0	0	14	0	0
	%	0	0	70	0	0
Above Phytotoxic	n	19	19	NK	20	2
	%	95	95	--	100	10
Calculated Values (n=20)[4]						
Above Phytotoxic	n	19	20	NK	20	2
	%	95	100	--	100	10
Correct calculation of phytotoxicity or non-phytotoxicity.	n	20	19	NK	20	19
	%	100	95	--	100	95
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	7	6	NK	1	15
	%	35	30	--	5	75
Correlation Coefficient[5]		0.8075*	0.9967*	0.3209	0.9300*	0.8073*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (see Table 3-5).
3 Based on laboratory determined total element concentration ($\mu g/g$).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

Ninety-five percent of the laboratory samples were above the As and Cu phytotoxic levels, while all samples exceeded the Zn phytotoxic level. Two samples (10%) had Pb concentrations that exceeded the phytotoxic Pb level of 1000 μg/g.

Like Site 10, the number of samples that were calculated as phytotoxic, based upon XRF index data, were similar to the number of laboratory determined phytotoxic samples. From the field XRF index data, 19, 20 and 20 samples were calculated as having exceeded the phytotoxic levels for As, Cu and Zn, respectively. The percent of samples that were correctly calculated phytotoxic was likewise high ($\geq$95%). We are 95 percent confident that 35, 30, 5 and 75 percent of the samples values were correctly calculated for As, Cu, Zn, and Pb, respectively.

With the exception of Fe, correlation coefficients for the target elements were significant ($P \leq .05$); As was 0.807, Cu was 0.996, Zn was 0.930 and Pb was 0.817. These results were consistent with those from Site 10 and indicated that the XRF spectrometer could accurately determine the concentrations of As, Cu, Zn and Pb at this site.

Site 12 had more bare ground than Site 10 and also more total plant coverage (Table 3-9). The reason for the greater plant coverage was that the vegetation on this site consisted of clumps of plants; each clump consisting of multiple layers of canopy. Unlike Site 10, which was dominated by grasses, Site 12 was dominated by shrubs, particularly willow and Wood's rose. Grasses and grass-like plants consisted almost entirely of redtop, but species of sedge and tufted hairgrass were also present. Forbs were more common and had more canopy coverage on this site than on Site 10. Total vegetation production was less than 175 lb/A (196 kg/ha), which was substantially less than undisturbed native rangeland.

Site No. 24

This three acre (1.2 ha) site, located about 2 miles southeast of Garrison at an approximate elevation of 4465 feet (1361 m), was also situated immediately adjacent to the Clark Fork River on the lowest floodplain level (Map 7, Oversize). The site consisted of tailings and soil underlain by alluvial gravel.

TABLE 3-9

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 12 -- BARE TAILINGS, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Agrostis alba	Redtop	13.9	30.9
Carex species	Sedge	0.8	1.8
Deschampsia caespitosa	Tufted hairgrass	0.8	1.8
Juncus balticus	Baltic rush	0.2	0.4
		15.7	34.9
Forbs			
Glycyrrhiza lepidota	Wild licorice	4.2	9.3
Melilotus officinalis	Yellow sweetclover	3.6	8.0
Equisetum species	Horsetail	2.4	5.3
Cirsium arvense	Canada thistle	1.4	3.1
Centaurea maculosa	Spotted knapweed	0.6	1.3
		12.2	27.2
Shrubs			
Rosa woodsii	Wood's rose	10.8	24.0
Salix species	Willow	5.6	12.4
Symphoricarpos occidentalis	Western snowberry	0.7	1.6
		17.1	38.0
	TOTALS	45.0	100.0
Total Bare Ground = 86.2%			

Mean concentrations of As (540 μg/g), Cu (3444 μg/g), and Zn (1753 μg/g) exceeded phytotoxic criteria (Tables 3-10 and 3-5). Like the other Bare Tailings sites, Site 24 had a high percentage of samples that exceeded phytotoxic criteria for As, Cu and Zn. Sixteen and 18 samples exceeded the phytotoxic levels for As and Zn, respectively. All samples had phytotoxic Cu concentrations. Only 5 percent of the samples were phytotoxic for Pb. As expected, most samples (at least 80% for each analyte) were calculated to be phytotoxic for As, Cu and Zn. The number of samples correctly calculated as phytotoxic was equal to or exceeded 18 (90%) for all elements. Based on the confidence interval, we are 95 percent confident that As, Cu, Zn and Pb were correctly calculated in 40, 30, 45 and 75 percent of the samples, respectively.

Correlation coefficients were significant ($P \leq .05$) for all elements, indicating that reliable calculations As, Cu, Fe, Zn and Pb can be made using the XRF spectrometer on this site.

Site 24 was the most vegetated of the Bare Tailings sites; total plant canopy coverage was greater, and the percentage of bare ground was less than Sites 10 or 12. There was also a litter component of the ground cover at this site. Perennial grasses dominated this site, particularly tufted hairgrass and redtop (Table 3-11). Canopy coverage of grasses and grass-like species was 35.2 percent, or about 73 percent of the total plant coverage. Forbs were an important component on this site, constituting about 20 percent of the total plant coverage. Cattails and spotted knapweed were the dominant forbs. Waterbirch was the dominant shrub species.

3.3.4.2 Buried Tailings Sites

Site No. 04

Located 0.75 miles (1.2 km) south of Garrison Junction, Site 04 occupied about 5 acres (2 ha) south of the Clark Fork River, on the inside of an oxbow (Map 7, Oversize). The area was on the lowest floodplain, at an elevation of approximately 4455 feet (1358 m). Site 04

TABLE 3-10.

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 24.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		540	3444	21590	1753	389
Minimum-Maximum		15-1950	138-19400	11400-29000	168-8150	16-1380
Standard Deviation		565	4834	5208	1863	347
Below Background	n	1	0	7	0	0
	%	5	0	35	0	0
Above Phytotoxic	n	16	20	NK	18	1
	%	80	100	--	90	5
Calculated Values (n=20)[4]						
Above Phytotoxic	n	16	18	NK	19	1
	%	80	90	--	95	5
Correct calculation of phytotoxicity or non-phytotoxicity.	n	19	18	NK	19	18
	%	95	90	--	95	90
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	8	6	NK	9	15
	%	40	30	--	45	75
Correlation Coefficient[5]		0.9370*	0.9960*	0.8134*	0.9845*	0.7637*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

TABLE 3-11

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 24 -- BARE TAILINGS, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Deschampsia caespitosa	Tufted hairgrass	19.6	40.6
Agrostis alba	Redtop	11.4	23.6
Carex species	Sedge	1.1	2.3
Poa pratensis	Kentucky bluegrass	0.9	1.2
Juncus balticus	Baltic rush	<0.1*	0.1
Unidentified Grasses		2.4	5.0
		35.2	72.8
Forbs			
Typha latifolia	Cattail	3.8	7.9
Centaurea maculosa	Spotted knapweed	3.3	6.8
Urtica dioicia	Stinging nettle	1.4	2.9
Unidentified Forbs		0.9	1.9
		9.4	19.5
Shrubs			
Betula occidentalis	Birch	3.8	7.9
Rosa woodsii	Wood's rose	<0.1	0.1
Salix species	Willow	<0.1	0.1
		3.7	7.7
	TOTALS	48.3	100.0
Total Bare Ground = 38.6%			
* Values of <0.1 were tabulated at 0.05.			

was partially dissected by an old river channel. Buried layers of tailings and mixed tailings/soil were underlain by alluvial gravel. The site was separated in half along the east-west axis by the abandoned Milwaukee Road right-of-way.

Mean concentrations of As (437 μg/g), Cu (3151 μg/g) and Zn (2419 μg/g) exceeded phytotoxic soil concentrations (Table 3-12). No samples were found to have less than background levels of As, Cu, Zn or Pb; however, 4 samples had less than the background level of Fe. The phytotoxic levels for As and Zn were exceeded in 15 (75%) and 16 (80%) of the samples, respectively. All samples were determined to be phytotoxic in terms of Cu. None of the samples were phytotoxic for Pb.

Arsenic, Cu, Zn and Pb were calculated phytotoxic in 16, 18, 19 and 0 samples, respectively. Correct calculations were made for As, Cu, Zn and Pb in at least 85 percent of the samples, thus indicating high accuracy in using XRF index values to calculate phytotoxic soil concentrations for these elements at this site. Based on the confidence intervals, the concentrations of As, Cu, Zn and Pb were correctly calculated (at the 95% confidence level) for 35, 70, 85 and 100 percent of the samples, respectively. Laboratory determined concentrations were significantly correlated ($P \leq .05$) with XRF index values for all elements on Site 04. Correlation coefficients ranged from 0.553 for Fe to 0.934 for Cu. These data confirm that the XRF spectrometer can be used to accurately determine the concentrations of these elements on this site.

Despite mean phytotoxic concentrations of As, Cu, and Zn, vegetation data indicated healthy and thriving plant communities. Seventeen plant species were encountered during sampling, comprising a total of 75.6 percent canopy coverage (Table 3-13). This was substantially greater than the 43.4 percent coverage found for the Bare Tailings sites, and approached the 90 percent coverage reported for undisturbed native rangeland (USDA, 1982).

Site 04 was dominated by grasses and grass-like plants. Redtop (39.4% coverage) had more than half of the total plant coverage (75.6 % composition). Baltic rush (7.7%) and tufted hairgrass (6.0%) were also significant components of this plant community. Canada thistle

TABLE 3-12

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 4.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		437	3151	22700	2419	288
Minimum-Maximum		49-1460	177-8200	18000-31200	217-5310	27-442
Standard Deviation		382	2456	3950	1498	196
Below Background	n	0	0	4	0	0
	%	0	0	20	0	0
Above Phytotoxic	n	15	20	NK	16	0
	%	75	100	--	80	0
Calculated Values (n=20)[4]						
Above Phytotoxic	n	16	18	NK	19	0
	%	80	90	--	95	0
Correct calculation of phytotoxicity or non-phytotoxicity.	n	17	18	NK	17	20
	%	85	90	--	85	100
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	7	14	NK	17	20
	%	35	70	--	85	100
Correlation Coefficient[5]		0.8475*	0.9336*	0.5532*	0.9060*	0.8811*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

TABLE 3-13

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 4 -- BURIED TAILINGS, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Agrostis alba	Redtop	39.4	52.1
Juncus balticus	Baltic rush	7.7	10.2
Deschampsia caespitosa	Tufted hairgrass	6.0	7.9
Poa species	Bluegrass	0.9	1.2
Carex species	Sedge	0.5	0.7
Hordeum jubatum	Foxtail barley	0.9	0.5
Agropyron smithii	Western wheatgrass	0.2	0.3
		55.1	72.9
Forbs			
Cirsium arvense	Canada thistle	5.2	6.9
Geranium species	Geranium	4.1	5.4
Haplopappus armeroidea	Thrift goldenweed	2.0	2.6
Trifolium species	Clover	0.9	1.2
Equisetum species	Horsetail	0.7	0.9
Iris missouriensis	Missouri iris	<0.1*	<0.1
Unidentified Forbs		1.4	1.9
		14.3	18.9
Shrubs			
Symphoricarpos occidentalis	Western snowberry	4.5	6.0
Rosa woodsii	Wood's rose	1.6	2.1
Salix species	Willow	0.1	0.1
		6.2	8.2
	TOTALS	75.6	100.0
Total Bare Ground = 9.1%			
* Values of <0.1 were tabulated at 0.05.			

(5.3%) and geranium (4.1%) were the dominant forbs. Snowberry and Wood's rose were clumped in the open areas away from the river while waterbirch lined the river channel.

Production was about 1650 lb/A (1850 kg/ha) which was similar to the 1800 lb/A (2018 kg/ha) typical of excellent native rangeland.

Site No. 27

This 8.3 acre (3.3 ha) site was located south of Deer Lodge just east of the Clark Fork River near the eastern edge of the floodplain at an elevation of 4535 feet (1382 m) (Map 7, Oversize). The area was mantled by a thin organic topsoil overlying a thin (0.25-0.5 ft, (0.08-0.15 m)) layer of tailings material which, in turn, was underlain by a buried soil. The area was underlain by alluvial gravel at depth. The site had a shallow water table (about 1.0 ft, (0.3 m)) and bordered mesic areas to the north and south. Element statistics on this site were similar to those of Site 04. Mean concentrations of As (401 μg/g), Cu (2636 μg/g) and Zn (1638 μg/g) exceeded phytotoxic levels (Tables 3-14 and 3-5). Three, four, and one sample(s) were determined to have levels of As, Fe and Zn that were below background soil concentrations. Laboratory data indicated, however, that most of the samples had concentrations of As, Cu and Zn that exceeded phytotoxic levels. A phytotoxic level of Pb was not determined in any sample.

Using XRF index values and the regression equations, As, Cu, Zn, and Pb were calculated phytotoxic in 95, 95, 75 and 5 percent of the samples, respectively. Correct calculations of phytotoxicity or non-phytotoxicity occurred for these elements in 70, 90, 90 and 95 percent of the samples. At the 95 percent confidence interval, As, Cu, Zn and Pb were correctly calculated in 25, 50, 35 and 60 percent of the samples, respectively. Correlation coefficients were high and significant ($P \leq .05$) for all elements. Copper (0.900) had the highest correlation while Fe (.617) had the lowest.

Despite excessive soil element levels, this site had very good plant growth. Total plant canopy coverage was 84.1 percent and bare ground covered only about 3 percent of the site (Table 3-15). Site 27 was dominated by grasses and grass-like plants, which had about 61

TABLE 3-14

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 27.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		401	2636	23350	1638	442
Minimum-Maximum		11-890	42-5890	14800-33800	76-4260	19-960
Standard Deviation		336	2266	4685	1638	361
Below Background	n	3	0	4	1	0
	%	15	0	20	5	0
Above Phytotoxic	n	13	17	NK	15	0
	%	65	85	--	75	0
Calculated Values (n=20)[4]						
Above Phytotoxic	n	19	19	NK	15	1
	%	95	95	--	75	5
Correct calculation of phytotoxicity or non-phytotoxicity.	n	14	18	NK	18	19
	%	70	90	--	90	95
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	5	10	NK	7	12
	%	25	50	--	35	60
Correlation Coefficient[5]		0.7531*	0.9009*	0.6179*	0.8482*	0.7281*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

TABLE 3-15

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 27 -- BURIED TAILINGS, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Juncus balticus	Baltic rush	35.0	39.1
Carex species	Sedge	9.2	10.3
Agrostis alba	Redtop	5.8	6.5
Poa pratensis	Kentucky bluegrass	2.2	2.5
Sporobolus cryptandrus	Sand dropseed	2.2	2.5
Poa species	Bluegrass	1.4	1.6
Hordeum jubatum	Foxtail barley	1.3	1.5
Agropyron caninum	Bearded wheatgrass	0.6	1.0
Agropyron species	Wheatgrass	0.1	0.1
Unidentified Grasses		2.9	3.2
		61.0	68.1
Forbs			
Potentilla anserina	Common silverweed	7.9	8.8
Cirsium arvense	Canada thistle	6.3	7.0
Senecio vulgaris	Common groundsel	5.8	6.1
Iris missouriensis	Missouri iris	1.3	1.5
Aster species	Aster	0.6	1.0
Erigeron glabellus	Smooth daisy	0.6	0.3
Cicuta douglassii	Water hemlock	0.6	0.7
Haplopappus armeroidea	Thrift goldenweed	0.6	0.7
Cardaria draba	Whitetop	0.3	0.3
Taraxacum officinale	Dandelion	0.3	0.3
Smilacina stellata	False Solomon's seal	0.2	0.2
Equisetum species	Horsetail	<0.1*	0.1
Unidentified Forbs		3.8	4.2
		28.7	31.9
	TOTALS	89.7	100.0
Total Bare Ground = 2.8%			
* Values of <0.1 were tabulated at 0.05.			

percent canopy coverage. The site consisted of large areas of Baltic rush interspersed with varying compositions of sedge, redtop and bluegrasses. Forbs had about 23 percent canopy coverage, or about 32 percent of the total canopy coverage. Common silverweed, Canada thistle and common groundsel were the dominant forbs. In contrast to Site 04, shrubs were absent from this site. Compared to undisturbed native range production was considered good; it was estimated at about 1600 lb/A (1794 kg/ha).

Site No. 28

Site 28 occupied 6.9 acres (2.7 ha) about 0.75 miles (1.2 km) east of Galen at an elevation of 4718 feet (1438 m) (Map 7, Oversize). The site was located on the floodplain approximately 500 feet (152 m) west of the Clark Fork River. It had scattered areas of buried tailings materials and was underlain at depth by alluvial gravel.

Mean concentrations of As, Cu, Fe, Zn and Pb were 374, 1337, 13920, 1066, and 380 μg/g, respectively (Table 3-16). These values were similar to Sites 04 and 27 in that the phytotoxic soil concentration were exceeded for As, Cu and Zn. Laboratory determined concentrations of As, Cu and Zn exceeded phytotoxic criteria in at least 80 percent of the samples. No samples contained phytotoxic levels of Pb.

Calculated concentrations exceeded phytotoxic levels for As, Cu, Zn and Pb in 100, 100, 60 and 0 percent of the samples, respectively. In terms of phytotoxicity, correct calculations of these elements were obtained for 80, 100, 60 and 20 percent of the samples. We are 95 percent confident that 60 percent of the calculated Cu values and 40 percent of the calculated Zn values were correct. The confidence intervals surrounding the calculated values for As and Pb spanned the phytotoxic levels in the case of every sample. Therefore, we can not determine whether these samples have phytotoxic concentrations of As or Pb (at the 95 percent confidence level), based upon calculations of the XRF index values.

Correlation coefficients were significant ($P \leq .05$) for all elements and were also comparable to sites 04 and 27 (see Tables 3-16 and 3-5). Copper and Zn had the highest coefficients (0.986 and 0.988, respectively) and As had the lowest (0.701).

TABLE 3-16

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 28

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=5)[3]						
Mean		374	1337	13920	1066	380
Minimum-Maximum		90-850	176-21400	6200-21400	153-2560	51-812
Standard Deviation		362	1093	7031	988	345
Below Background	n	0	0	3	1	0
	%	0	0	60	5	0
Above Phytotoxic	n	4	5	NK	3	0
	%	80	100	--	60	0
Calculated Values (n=5)[4]						
Above Phytotoxic	n	5	5	NK	3	0
	%	100	100	--	60	0
Correct calculation of phytotoxicity or non-phytotoxicity.	n	4	5	NK	3	5
	%	80	100	--	60	100
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	0	3	NK	2	0
	%	0	60	--	40	0
Correlation Coefficient[5]		0.7012	0.9869*	0.9593*	0.9886*	0.7077

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

Despite high element concentrations in the soils, Site 28 was occupied by many plant species having extensive coverage and production. This pastureland site had a relatively homogeneous combination of plant species; no vegetation patterns were visually discernible. Redtop, aster, sand dropseed and thrift goldenweed dominated the site (Table 3-17). Like site 27, grasses and grass-like species were the dominant plant class and shrubs were completely absent. Total vegetation coverage was very high (92.1 %) and similar to native rangeland in excellent condition (90%). Production was estimated at about 1800 lbs/A (2018 kg/ha).

Site No. 30

This site was located about 5.5 miles (8.9 km) north of Deer Lodge in the active floodplain, about 500 feet (152 m) west of the Clark Fork River (Map 7, Oversize). The site was characterized by several abandoned river channels and by a shallow water table (about 0.25 ft (0.08 m)). This site was at an elevation of 4410 feet (1344 m). Test holes indicated that a thin (0.17 ft (0.05 m)) layer of tailings material was buried at shallow depths (<0.25 ft, <0.08 m) between highly organic topsoil and buried loam to silt loam soil. The area was likely underlain at depth by alluvial gravel.

Like the other Buried Tailings site, mean As, Cu and Zn concentrations exceeded phytotoxic levels, while the mean Pb value was less than the phytotoxic level (Table 3-18). No samples had below background As, Cu, Zn or Pb concentrations; however, Fe concentrations were below the background level in 2 samples. Phytotoxic levels were exceeded in most samples for As, Cu and Zn, but were exceeded in only one sample for Pb.

Arsenic, Cu, Zn and Pb were calculated phytotoxic in 95, 95, 95 and 5 percent of the samples, respectively. Correct calculations relative to the phytotoxic levels were made for these elements for at least 80 percent of the samples. Correct calculations (at the 95% confidence level) were made for As, Cu, Zn and Pb in 50, 65, 15 and 85 percent of the samples, respectively.

TABLE 3-17

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 28 -- BURIED TAILINGS, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Agrostis alba	Redtop	38.5	41.7
Sporobolus cryptandrus	Sand dropseed	9.6	10.3
Carex species	Sedge	2.7	2.9
Agropyron caninum	Bearded wheatgrass	2.0	2.2
Hordeum jubatum	Foxtail barley	1.4	1.5
Juncus balticus	Baltic rush	0.2	1.5
Poa pratensis	Kentucky bluegrass	0.5	0.5
Poa species	Bluegrass	0.2	0.2
Unidentified Grasses		1.8	2.0
		57.6	62.5
Forbs			
Aster species	Aster	20.3	22.0
Haplopappus armeroidea	Thrift goldenweed	6.2	6.7
Cirsium arvense	Canada thistle	2.7	2.9
Trifolium species	Clover	1.4	1.5
Senecio vulgaris	Common groundsel	0.5	1.5
Smilacina stellata	False Solomon's seal	0.3	0.3
Equisetum species	Horsetail	0.2	0.2
Unidentified Forbs		2.9	3.1
		34.5	37.5
	TOTALS	92.1	100.0
Total Bare Ground = 14.4%			

TABLE 3-18

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRAITONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 30.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		429	2661	22030	1982	371
Minimum-Maximum		42-1270	61-8120	10600-29800	95-5980	24-2140
Standard Deviation		321	2115	3964	1471	460
Below Background	n	0	0	2	0	0
	%	0	0	10	0	0
Above Phytotoxic	n	15	19	NK	16	1
	%	75	95	--	80	5
Calculated Values (n=20)[4]						
Above Phytotoxic	n	19	19	NK	19	1
	%	95	95	--	95	5
Correct calculation of phytotoxicity or non-phytotoxicity.	n	16	20	NK	17	20
	%	80	100	--	85	100
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	10	13	NK	3	17
	%	50	65	--	15	85
Correlation Coefficient[5]		0.8782*	0.9260*	0.6995*	0.6918*	0.9108*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

Correlation statistics were similar to those for the other Buried Tailings sites. The coefficients were high and significant ($P \leq .05$) for all the elements. Copper had the highest correlation (0.926) and Zn had the lowest (0.691).

This was one of the most species rich sites studied, with 24 plant species encountered during sampling. Several old river channels were visible on this site; these channels influenced vegetation patterns to a large degree. The site was dominated by grasses and grass-like species, particularly redtop (26.8%), Baltic rush (15.0%) and sedge (14.8%) (Table 3-19). Common silverweed, Canada thistle and Missouri iris were the most abundant forbs. Unlike sites 27 and 28, shrubs were a conspicuous component of site 30. Wood's rose, the dominate shrub, was scattered across the site in association with various grasses, but was also present in dense clumps in some areas. Dense stands of willow were located along the river channel.

3.3.4.3 Good Plant Growth Sites

These sites were hayfields situated above the active floodplain. The owners of these fields stated that their particular field had never been flooded with water from the Clark Fork River, either through natural flooding or irrigation.

Site No. 09

This 6.2 acre (2.5 ha) site was located approximately 4.5 miles (7.2 km) south of Deer Lodge at an elevation of 4640 feet (1414 m) (Map 7, Oversize). This site was on a slightly sloping bench land, approximately 30 feet (9.2 m) above the river channel and about 800 feet (244 m) east of the river. The area was characterized by shallow soils underlain by gravel with some gravelly areas exposed at the surface.

Mean element concentrations were much lower at this site compared to levels encountered at the Bare Tailings and Buried Tailings sites. For most of the samples, the concentration of As, Zn and Pb were between background and phytotoxic levels (Table 3-20). None of these samples had laboratory concentrations of these elements that were greater than the

TABLE 3-19

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 30 -- BURIED TAILINGS, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Agrostis alba	Redtop	26.8	32.1
Juncus balticus	Baltic rush	15.0	17.9
Deschampsia caespitosa	Tufted hairgrass	2.3	2.7
Carex species	Sedge	14.8	17.7
Agropyron species	Wheatgrass	0.2	0.2
Agropyron smithii	Western wheatgrass	0.1	0.1
Poa sandbergii	Sandberg bluegrass	0.1	0.1
		59.3	70.9
Forbs			
Potentilla anserina	Common silverweed	4.8	5.8
Cirsium arvense	Canada thistle	3.2	3.8
Iris missouriensis	Missouri iris	2.6	3.1
Vicia americana	American vetch	0.5	0.6
Erigeron glabellus	Smooth daisy	0.5	0.6
Trifolim species	Clover	0.4	0.4
Smilacina stellata	False Solomon's seal	0.3	0.4
Aster falcatus	Creeping white prairie aster	0.2	0.3
Astragalus species	Milkvetch	0.2	0.3
Sisyrinchium angustifolium	Blue-eyed grass	<0.1*	<0.1
Unidentified Forbs		3.3	3.9
		16.1	19.2
Shrubs			
Rosa woodsii	Wood's rose	5.3	6.3
Symphoricaipos occidentalis	Western snowberry	1.7	2.0
Sheperdia canadensis	Buffaloberry	0.7	0.8
Salix species	Willow	0.1	0.2
Unidentified Shrubs		0.5	0.6
		8.3	9.9
	TOTALS	83.7	100.0
Total Bare Ground = 10.4%			
* Values of <0.1 were tabulated at 0.05.			

TABLE 3-20.

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 9.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		32	177	19485	121	30
Minimum-Maximum		8-52	14-350	2500-22600	38-199	15-49
Standard Deviation		10	76	4241	35	8
Below Background	n	1	1	7	2	1
	%	5	5	35	10	5
Above Phytotoxic	n	0	19	NK	0	0
	%	0	95	--	0	0
Calculated Values (n=20)[4]						
Above Phytotoxic	n	0	19	NK	0	0
	%	0	95	--	0	0
Correct calculation of phytotoxicity or non-phytotoxicity.	n	20	19	NK	20	0
	%	100	95	--	100	0
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	20	3	NK	20	20
	%	100	15	--	100	100
Correlation Coefficient[5]		-0.0632	0.6875*	-0.1706	0.6620*	0.0889

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

their respective phytotoxic levels. However, 95 percent of the samples had a Cu concentration that exceeded the phytotoxic level.

Identical results were obtained by calculating the concentration of these elements using field XRF index values and regression equations. All samples had less than phytotoxic concentrations of As, Zn and Pb, but most samples had phytotoxic concentrations of Cu. Relative to phytotoxic criteria, these values were calculated correctly for As, Cu, Zn and Pb in 100, 95, 100 and 100 percent of the samples, respectively. Copper was the only element that had less than 100 percent of the samples calculated correctly at the 95 percent confidence level; 15 percent of the Cu calculations were correct at this level.

Correlations coefficients were only significant ($P \leq .05$) for Cu and Zn at this site. No correlations were found between element concentrations and XRF index values for As, Fe and Pb.

This site had been dominated by sagebrush and native grasses before it was plowed and seeded to hay species about 10 years ago. The site was currently being irrigated from a well. Vegetation was homogeneous over the site and consisted of alfalfa, timothy and orchardgrass (Table 3-21). Production was estimated at about 2300 lb/A (2578 kg/ha), which was substantially greater than native rangeland and rated as good to excellent relative to other improved pastures.

Site No. 14

This 6.9 acre (2.8 ha) hayfield site was located 3.0 miles (4.8 km) southeast of Drummond, immediately north and up-slope from site 15, at an elevation of 4005 feet (1221 m) (Map 7, Oversize). Site 14 was located about 2300 feet (701 m) southwest of the Clark Fork River on the upland margin of the floodplain. Parent materials were likely alluvial gravel overlain by a thin veneer of finer textured colluvial sediments derived from the adjacent unconsolidated Tertiary sediments. Site 14 had never been irrigated with water from the Clark Fork River.

TABLE 3-21

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 9 -- GOOD PLANT GROWTH, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Phleum pratense	Timothy	25.9	32.8
Dactylis glomerata	Orchardgrass	9.0	11.4
Bromus inermis	Smooth brome	9.0	1.1
Bromus tectorum	Cheatgrass	0.4	0.5
		36.2	45.9
Forbs			
Medicago sativa	Alfalfa	41.1	52.1
Taraxacum officinale	Dandelion	1.6	2.0
		42.7	54.1
	TOTALS	78.9	100.0
Total Bare Ground = 15.6%			

Site 14 was used as the background site for this study because element concentrations were similar to mean levels found at non-anthropogenically contaminated sites from throughout the United States and at sites in the region of the Clark Fork River (see Table 3-5 for background data). Mean concentrations of As, Cu, Fe, Zn and Pb were 16, 29, 19,270, 82, and 15 μg/g, respectively (Table 3-22). None of the samples had values above the phytotoxic levels for these elements. All sample values were correctly calculated as being non-phytotoxic at the 95 percent confidence level.

Correlation coefficients were significant ($P \leq .05$) for all elements at this site. Values ranged from 0.470 for Fe to 0.784 for As.

Vegetation was a homogeneous mixture of orchardgrass, Kentucky bluegrass and alfalfa. Grasses represented approximately 78 percent of the total plant coverage (Table 3-23). The composition of alfalfa was only about 15 percent. Production was excellent; it was visually estimated at 2500 lb/A (2800 kg/ha).

Site No. 22

This 10 acre (4 ha) site was located about 0.3 miles (0.5 km) north of the town of Gold Creek at an elevation of 4175 feet (1273 m) (Map 7, Oversize). It was on the Clark Fork River floodplain, 400 feet (122 m) south of the river and less than 10 feet (3.0 m) above the level of the river. The area had about 2.5 feet (0.76 m) of soil material consisting of a silt loam underlain by a loamy sand. Parent material was alluvial gravel.

Site 22 had slightly greater mean soil concentrations of As, Cu, Zn and Pb than Site 14, the background site (Table 3-24). Laboratory analyses revealed that none of the samples had As or Pb concentrations above phytotoxic levels; however, Cu and Zn concentrations were above phytotoxic levels in 90 and 25 percent of the samples, respectively. Calculated values were similar to laboratory values. At least 90 percent of the calculated values were correctly determined, in terms of phytotoxicity. We are 95 percent confident that 100 percent of the As values, 20 percent of the Cu values, 30 percent of the Zn values and 100 percent of the

TABLE 3-22.

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 14.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		16	29	19270	82	15
Minimum-Maximum		7-34	13-63	16800-21800	47-184	10-24
Standard Deviation		11	10	1240	30	3
Below Background	n	13	11	13	13	10
	%	65	55	65	65	50
Above Phytotoxic	n	0	0	NK	0	0
	%	0	0	--	0	0
Calculated Values (n=20)[4]						
Above Phytotoxic	n	0	0	NK	0	0
	%	0	0	--	0	0
Correct calculation of phytotoxicity or non-phytotoxicity.	n	20	20	NK	20	20
	%	100	100	--	100	100
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	20	20	NK	20	20
	%	100	100	--	100	100
Correlation Coefficient[5]		-0.7847*	0.7721*	0.4706*	0.5190*	0.5709*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

TABLE 3-23

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 9 -- GOOD PLANT GROWTH, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Dactylis glomerata	Orchardgrass	43.3	45.8
Poa species	Bluegrass	28.4	30.0
Bromus inermis	Smooth brome	1.7	1.8
		73.4	77.6
Forbs			
Medicago sativa	Alfalfa	14.5	15.3
Taraxacum officinale	Dandelion	6.7	7.1
		21.2	22.4
	TOTALS	97.9	100.0
Total Bare Ground = 10.4%			

TABLE 3-24

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRAITONS (μg/g), CALCULATEDVALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 22

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		36	265	18201	379	52
Minimum-Maximum		11-83	28-652	1920-21100	70-837	17-89
Standard Deviation		19	145	4380	221	15
Below Background	n	2	1	9	1	0
	%	10	5	45	5	0
Above Phytotoxic	n	0	18	NK	5	0
	%	0	90	--	25	0
Calculated Values (n=20)[4]						
Above Phytotoxic	n	0	20	NK	6	0
	%	0	100	--	30	0
Correct calculation of phytotoxicityor non-phytotoxicity.	n	20	18	NK	19	20
	%	100	90	--	95	100
Correct calculation of phytotoxicityor non-phytotoxicityat the 95% confidence level.	n	20	4	NK	6	20
	%	100	20	--	30	100
Correlation Coefficient[5]		-0.4461*	0.6626*	0.1086	0.9002*	-0.3564

1 Background values were mean element concentrationsfrom Site 14 (See Table 3-5).
2 Phytotoxicvalues were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

Pb values were correctly calculated at greater than their phytotoxic level. Correlation coefficients were significant ($P \leq .05$) for As, Cu and Zn, but not for Fe or Pb.

The site consisted of alfalfa, smooth brome and Kentucky bluegrass. Grasses accounted for about 40 percent of the total vegetation coverage (Table 3-25). Production was excellent at approximately 3000 lb/A (3360 kg/ha).

3.3.4.4 Historically Irrigated Sites

These sites had been historically irrigated with Clark Fork River water. The irrigated sites were located on the highest level of the floodplain and, at the time of sampling, were being used for hay production.

Site No. 15

Site 15 was a hayfield located about 3.0 miles (4.8 km) south-east of Drummond at an elevation of approximately 3995 feet (1218 m) (Map 7, Oversize). This 10 acre (4.1 ha) site was about 15 feet (4.6 m) above the level of the river. Site 15 was southwest of the Clark Fork River, immediately downslope from Site 14. Parent material was likely alluvial gravel.

This site had definitely been anthropogenically impacted by contaminated water, judging from the concentrations of the target elements in the soil. None of the samples had element concentrations below background levels and mean element concentrations were above phytotoxic levels for As (101 μg/g), Cu (1537 μg/g) and Zn (1868 μg/g) (Table 3-26). Forty-five, 100 and 100 percent of the samples were above the phytotoxic levels for As, Cu and Zn, respectively. None of the samples had phytotoxic concentrations of Pb. Values were calculated correctly - in terms of phytotoxicity - for As, Cu, Zn and Pb in 85, 100, 100 and 100 percent of the samples, respectively. At the 95 percent confidence level, 100 percent of the Cu values, 60 percent of the Zn values, and 100 percent of the Pb values were correctly calculated. In terms of As, we were not confident that any of the calculated values exceeded the phytotoxic limit.

TABLE 3-25

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 22 -- GOOD PLANT GROWTH, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Bromus inermis	Smooth brome	19.8	15.8
Poa pratensis	Kentucky bluegrass	14.2	11.3
Agropyron dasystachyum	Thickspike wheatgrass	9.6	7.6
Agropyron smithii	Western wheatgrass	2.9	2.3
Agropyron species	Wheatgrass	1.0	0.8
Phleum pratense	Timothy	1.0	0.8
Bromus tectorum	Cheatgrass brome	0.7	0.6
		49.2	39.2
Forbs			
Medicago sativa	Alfalfa	71.2	56.7
Taraxacum officinale	Dandelion	4.7	3.7
Sisymbrim loeselii	Tumblemustard	0.4	0.8
		76.3	60.8
	TOTALS	125.5	100.0
Total Bare Ground = 8.3%			

TABLE 3-26

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION, AND CORRELATION COEFFICIENTS FOR SITE 15.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		101	1537	24510	1868	178
Minimum-Maximum		58-180	712-2690	22400-26200	756-3910	90-288
Standard Deviation		37	593	1337	1083	52
Below Background	n	0	1	0	0	0
	%	0	5	0	0	0
Above Phytotoxic	n	9	20	NK	20	0
	%	45	100	--	100	0
Calculated Values (n=20)[4]						
Above Phytotoxic	n	10	20	NK	20	0
	%	50	100	--	100	0
Correct calculation of phytotoxicity or non-phytotoxicity.	n	17	20	NK	20	20
	%	85	100	--	100	100
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	0	20	NK	12	20
	%	0	100	--	60	100
Correlation Coefficient[5]		0.6430*	0.8862*	0.4888*	0.9314*	0.5140*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

Correlation coefficients were significant ($P \leq .05$) for all elements. Excellent correlations were obtained for Cu (0.886) and Zn (0.931). These data indicated a high degree of confidence in using XRF index values and the regression equation to calculate the concentration of the target elements, especially Cu and Zn. This site consisted of a relatively uniform association of alfalfa, smooth brome and Kentucky bluegrass. Alfalfa dominated the site, accounting for about 83 percent of the total plant coverage (Table 3-27).

The site had several old ditches running through it, which had been filled-in and the banks leveled by repeated plowing to more than a foot in depth. The owner stated that production in this field had historically been poor, but had steadily improved over the years. He also stated that in certain places, particularly where a ditch was present, vegetation growth was noticeably poor and plants often "yellowed" sooner than in other areas of the field. Production was visually estimated at about 1800 lbs/A (2018 kg/ha), which was substantially less than the site could have produced had it not been contaminated. The uncontaminated background site (Site 14) was less than 500 ft (152 m) away and was producing about 2500 lbs/A (2800 kg/ha).

Site No. 25

Site 25 occupied about 5.5 acres (2.2 ha) of irrigated pasture approximately 2.75 miles (4.4 km) south of Deer Lodge (Map 7, Oversize). The site was at an elevation of 4585 feet (1398 m) and 1400 feet (427 m) east of the Clark Fork River. The area was on the upland margin of the active floodplain and consisted of shallow soils underlain by alluvial gravel. This site was west and downslope of the Valiton ditch, which was the source of Clark Fork River water.

The owner stated that this field had been irrigated with water from the Clark Fork when the river was "running red". Like Site 15, Site 25 was contaminated with As, Cu, Zn and Pb. Mean concentrations of As (109 μg/g), Cu (894 μg/g), Zn (291 μg/g) and Pb (106 μg/g) were substantially greater than background levels (Tables 3-28 and 3-5). Arsenic and Cu concentrations were equal to or greater than phytotoxic levels in 60 and 90 percent of the samples, respectively. None of the samples had phytotoxic concentrations of Zn or Pb.

TABLE 3-27

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 15 -- HISTORICALLY IRRIGATED, JULY 1987, CFRSS

	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Bromus inermis	Smooth brome	4.6	6.1
Poa pratensis	Kentucky bluegrass	4.4	5.8
Phleum pratense	Timothy	2.4	3.2
Dactylis glomerata	Orchardgrass	1.3	1.7
		12.7	16.8
Forbs			
Medicago sativa	Alfalfa	60.0	79.4
Trifolium species	Clover	2.5	3.3
Taraxacum officinale	Dandelion	0.4	0.5
		62.9	83.2
	TOTALS	75.6	100.0
Total Bare Ground = 37.8%			

TABLE 3-28

STATISTICS FOR LABORATORY DETERMINED ELEMENT CONCENTRATIONS (μg/g), CALCULATED VALUES (FROM XRF AND LABORATORY VALUE REGRESSION EQUATION), AND CORRELATION COEFFICIENTS FOR SITE 25.

		Arsenic	Copper	Iron	Zinc	Lead
Background/Phytotoxic Values						
Background[1]		16	29	19270	82	15
Phytotoxic[2]		100	100	NK	500	1000
Laboratory Values (n=20)[3]						
Mean		109	894	24170	291	106
Minimum-Maximum		9-310	29-2190	17000-28800	61-449	19-213
Standard Deviation		64	573	3434	97	50
Below Background	n	1	0	2	2	0
	%	5	0	10	10	0
Above Phytotoxic	n	12	18	NK	0	0
	%	60	90	--	0	0
Calculated Values (n=20)[4]						
Above Phytotoxic	n	15	20	NK	0	0
	%	75	100	--	0	0
Correct calculation of phytotoxicity or non-phytotoxicity.	n	10	18	NK	20	20
	%	50	90	--	100	100
Correct calculation of phytotoxicity or non-phytotoxicity at the 95% confidence level.	n	0	6	NK	15	20
	%	0	30	--	75	100
Correlation Coefficient[5]		0.2498	0.7094*	0.5744*	0.6028*	0.4950*

1 Background values were mean element concentrations from Site 14 (See Table 3-5).
2 Phytotoxic values were derived from EPA 1986 and EPA 1987b (See Table 3-5).
3 Based on laboratory determined total element concentration (μg/g).
4 Calculated using regression equation of laboratory generated total concentration and field XRF index value.
5 Coefficients marked with * are significant at $P \leq 0.05$.
NK Not known; phytotoxic Fe levels are not known.

Calculated values were similar to the laboratory determined values. In terms of phytotoxicity, correct calculations were made for As, Cu, Zn and Pb in 50, 90, 100 and 100 percent of the samples, respectively. At the 95 percent confidence level, correct calculations, relative to phytotoxicity, were made for Cu, Zn, and Pb in 30, 75 and 100 percent of the samples, respectively.

Correlation coefficients were significant ($P \leq .05$) for Cu, Zn, Fe and Pb, but not for As. Correlation values were low, relative to the other Historically Irrigated site.

Vegetation cover was 23 percent at this site but about 84 percent of the site's surface was devoid of plant matter (Table 3-29). Of the plant species present, the site was dominated by basin wildrye, a large native bunchgrass common in the floodplains of western Montana. The occurrence of this species indicated that this site had probably never been plowed or interseeded. Production was less than 500 lb/A (560 kg/ha); however, according to the owner, production has been improving on this site.

3.3.5 Summary and Conclusions

3.3.5.1 Site Summaries

Summary of Bare Tailings Sites

Study sites exhibiting large areas of barren tailings material on the surface included Sites 10, 12 and 24. These sites were a mosaic of bare tailings and scattered clumps of grasses and shrubs. Copper and zinc salts were often conspicuous on the surface of the ground.

Laboratory element concentrations of As, Cu, Zn and Pb on these sites were from one to two orders-of-magnitude greater than background values. All the Bare Tailings Sites had a high percentage of samples whose laboratory concentrations exceeded phytotoxic criteria for As, Cu and Zn. More than 96 percent of the samples taken from these sites had phytotoxic concentrations of As, Cu and Zn. Phytotoxic levels for Pb, however, were detected in only four samples collected from these sites.

TABLE 3-29

PLANT SPECIES, CANOPY COVERAGE AND COMPOSITION ON SITE 25 -- HISTORICALLY IRRIGATED, JULY 1987, CFRSS

Latin Binomial	Common Name	% Canopy Coverage	% Composition
Grass and Grass-like Plants			
Elymus cinereus	Basin wildrye	7.4	31.9
Agropyron smithii	Western wheatgrass	4.1	17.7
Poa compressa	Canada bluegrass	1.0	4.3
		12.5	53.9
Forbs			
Cirsium arvense	Canada thistle	5.7	24.6
Cardaria draba	Whitetop	4.4	19.0
Aster species	Aster	0.3	4.3
Chrysothamnus nauseosus	Rubber rabbitbrush	0.3	1.3
		10.7	46.1
	TOTALS	23.2	100.0
Total Bare Ground = 84.1%			

Correlation coefficients for As, Cu, Zn and Pb were significant ($P \leq .05$) on all Bare Tailings sites. This indicated that the XRF spectrometer could be used to accurately determine the concentration of these elements on these type of sites (i.e. site having high concentrations of these elements).

The percentage of samples that were calculated as phytotoxic was also high for As, Cu, Zn and Pb, because the laboratory values were so much greater than the phytotoxic levels, and because the correlations between the XRF values and the laboratory values were significant ($P \leq .05$). For the same reasons (high concentrations and high correlations) the percentage of samples that were correctly calculated as phytotoxic (or non-phytotoxic) was also high; more than 90 percent of the samples were correctly calculated for As, Cu, Zn and Pb.

Due to the phytotoxic soil concentrations of As, Cu, Zn and Pb, the vegetation on these sites was experiencing physiological stress. This stress may be further compounded by low pH, high EC (see Appendix G), and the possible synergistic effects of several elements. These harsh growing conditions were manifested in low amounts of plant canopy coverage, low production, low numbers of plant species, and large areas of bare ground.

Total plant canopy coverage on the Bare Tailings sites ranged from 35.6 percent on Site 10 to 48.3 percent on Site 24. These figures were substantially less than undisturbed native rangeland, which typically has about 90 percent vegetation coverage when in excellent condition (USDA 1982). Vegetation production was also less than would be expected on native range. In this physiographic position, undisturbed rangeland averages about 1800 lb/A (2018 kg/ha), compared to less than 250 lb/A (280 kg/ha) for the Bare Tailings sites.

Summary of Buried Tailings Sites

Element data were similar to that found for the Bare Tailings sites. The Buried Tailings sites were characterized by mean total concentrations for the target elements that were substantially elevated above background. In fact, like the Bare Tailings sites, mean concentrations for As, Cu and Zn exceeded phytotoxic criteria, indicating that physiological stress to the vegetation may have been occurring. Correlation coefficients, expressing the

relationship between XRF index values and laboratory determined concentrations, were significant ($P \leq .05$) for all elements at all sites. Thus, for sites having buried tailings with these levels of contamination, the XRF spectrometer can be used to accurately ascertain the concentration of these elements.

Correct calculations of phytotoxicity or non-phytotoxicity were made for As, Cu, Zn and Pb in at least 60 percent of the samples. Correct calculations at the 95 percent confidence level varied between the sites.

Despite the phytotoxic soil concentrations on these sites, the vegetation was characterized by high amounts of canopy coverage, high production, numerous plant species, and low amounts of bare ground. This differed from the Bare Tailings sites which had similar levels of the target elements but demonstrated poor plant performance. In general, metal levels were elevated in materials identified as tailings compared to those identified as soils, regardless of depth within the profile. There were exceptions to this general trend (see Appendix G). Relative to undisturbed native rangeland, the Buried Tailings sites were in excellent vegetative condition. Canopy coverage averaged 85.3 percent for these sites, which was similar to the 90 percent typical of native rangeland in excellent condition. Production was also similar to excellent condition native rangeland.

Summary of Good Plant Growth Sites

Site 14 was used as the background site for this investigation because it had the lowest mean concentrations of the target elements and because these values were similar to values from other sites that were considered to be free of anthropogenic contamination.

Sites 09 and 22 did not have any samples that exceeded phytotoxic criteria for As or Pb. Most of the samples - at least 90 percent - from these two sites contained phytotoxic concentrations of Cu. Twenty-five percent of the samples from Site 22 contained phytotoxic concentrations of Zn. Calculated concentrations of the target elements were similar to the laboratory determined concentrations. Correct calculations, in terms of phytotoxicity, were made in $\geq$90 percent of the samples. Results were mixed for the correlation of XRF index

values and laboratory determined total element concentrations on the Good Plant Growth sites. Only about half of these correlations were significant ($P \leq .05$). In addition, some of the significant correlations revealed an inverse relationship (i.e. negative correlation) between the parameters. Inverse relationships occurred on all sites for some elements. These results were due to relatively low concentrations of the target elements in the soil (values were generally close to background levels).

These sites possessed good to excellent plant production and were dominated by introduced pastureland grasses and alfalfa. Plant canopy coverage on these sites averaged 99.7 percent and production averaged 2600 lb/A (2915 kg/ha). Bare ground averaged about 11 percent.

Summary of Historically Irrigated Sites

Based on soil chemistry data, the Historically Irrigated sites had been irrigated with contaminated water. Mean soil concentrations of As, and Cu from both sites were greater than the phytotoxic levels for these elements. The mean Zn value exceeded the phytotoxic level on Site 15. Calculated values were similar to the laboratory determined concentrations for all the elements on both sites. Correct calculations, in terms of phytotoxicity, were made for most samples and correlation coefficients were significant ($P \leq .05$) in most cases. These data indicated that the XRF spectrometer could be used to accurately determine the total soil concentrations of the target elements on these types of sites.

Plant canopy coverage was considered poor on Site 25 (23.2%) and good on Site 15 (75.6 %). Production was substantially less on both sites than it would have been had the sites not been contaminated. Site 15 - the hayfield site - was producing about 1800 lbs/A (2018 kg/ha), compared to about 2500 lbs/A (2800 kg/ha) being produced on the uncontaminated hayfield. Site 25 - the native rangeland site - was producing less than 500 lbs/A (560 kg/ha) compared to about 1800 lbs/A (2018 kg/ha) that is typically produced on native rangeland.

3.3.5.2 Conclusions

- The sites evaluated represented the full spectrum of contamination in the Clark Fork River Screening Study area. Site No. 14 had concentrations of the target elements that were similar to non-anthropogenically affected areas, while the Bare Tailings sites had target element concentrations that were one to two orders-of-magnitude greater than background levels. Other sites were evaluated that had target element concentrations within this range.

- For most elements and most sites there was a positive, significant correlation between field XRF index values and laboratory determined total concentrations. Therefore, in most instances the XRF spectrometer was able to assess the concentration of the target elements.

- For most of the elements on most sites, the XRF spectrometer was able to accurately evaluate a soil sample in terms of the phytotoxic level.

- Copper and arsenic were the target elements that most often exceeded phytotoxic levels.

- No correlation was apparent between the total element concentration in the soil samples and the amount of plant canopy coverage or plant production. The Buried Tailings sites had very high concentrations of the target elements present in the soil profile but had excellent plant cover and production. This must not be interpreted to mean that the metal levels were not phytotoxic. Factors other than soil element concentration such as cation exchange capacity, water holding capacity, nutrient status, depth to phytotoxic materials, non-phytotoxic soil horizons and tolerance of plant populations growing on the materials all influenced plant performance.

SECTION 4.0

4.0 SUMMARY OF OTHER SITE INVESTIGATIONS

The purpose of this section of the report is acquaint the reader with other environmental investigations which have been completed or commenced in the Upper Clark Fork River Basin since the Clark Fork Screening Study was completed in 1987. This information will benefit those responsible for evaluating current data gaps relative to study objectives described for this project. All studies and reports completed in the Upper Clark Fork River Basin since 1987 may not be identified herein. Future investigators of the Upper Clark Fork River Basin should perform a comprehensive literature search to identify other studies and/or reports which will further their understanding of the area.

We have organized this section such that identified studies and/or reports are arranged alphabetically. Complete references for published reports are contained in Section 5.0 of this report. Where possible, we provide a brief description of investigative components of the studies, the status of the projects, and conclusions reached by the various investigators.

Andrews (1987)

This study, completed by the U.S. Geological Survey, focused on evaluating metals in streambed sediments in the Clark Fork River. Sediment samples were collected from 21 locations along a 400 kilometer reach of the stream between the Warm Springs Ponds and the mouth of the Flathead River. Andrews concluded that arsenic, cadmium, copper, lead, and zinc concentrations in the sediment decrease downstream. He further stated that there is no evidence that an appreciable quantity of any trace metal is being dissolved from the sediment particles and is entering the fluid phase. The longitudinal distribution of trace metals associated with the fine-grained bed sediment in the Clark fork River appears to be solely the result of physical mixing of mill tailings with floodplain material deposited prior to mining.

Bahls (1989)

The water quality in the Clark Fork River and its tributaries were evaluated during this study based on the structure and composition of summer algae associations in the stream bottom periphyton community. Data used to develop this report were collected by the Montana Water Quality Bureau as described under Ingman and Kerr (1990).

Caciari and Watson (1988)

These investigators used a metal speciation model to estimate the percent of dissolved copper in the highly toxic free ion form for several sites on the Upper Clark Fork River. The purpose of this study was to evaluate the results of the metal speciation model with respect to possible effects on trout populations in the river. The hypothesis evaluated during this study was that water chemistry changes result in a conversion of a greater percent of the metals to their toxic free ion form as water moves downstream in the Clark Fork River.

Results of the study indicated that the model used did not show any dramatic downstream increase in the percent free copper in the Upper Clark Fork River, largely because there is no dramatic or consistent downstream change in pH and alkalinity. The report concluded that it is unlikely that the downstream drop in fish populations can be explained by copper speciation exclusively.

Ingman (1988a)

Ingman presented this summary report of heavy metals in the Clark Fork River to the Montana Governor's office. The report is based on routine surface water sampling on the Clark Fork River completed by the Montana Water Quality Bureau as described under Ingman and Kerr (1990).

Ingman (1988b)

Ingman prepared this report for the Montana Governor's Office to describe algal nutrients in the Clark Fork River system. The report is based on data developed through routine sampling in the Clark Fork River by the Montana Water Quality Bureau as described under Ingman and Kerr (1990).

Ingman (1988c)

Ingman prepared this report for the Montana Governor's Office to describe suspended sediment characteristics in the Clark Fork River system. The report is based on data developed through routine sampling in the Clark Fork River by the Montana Water Quality Bureau as described under Ingman and Kerr (1990).

Ingman (1987)

The author prepared this interim report to present and describe surface water quality data collected by the Montana Water Quality Bureau during early phases of their sampling program on the Clark Fork River. Information contained in the report is similar to that described in Ingman and Kerr (1990).

Ingman and Kerr (1990)

This report summarizes and interprets water quality data collected by the Montana Water Quality Bureau in the Clark Fork River Basin during state fiscal years 1988 and 1989. The Water Quality Bureau has performed routine surface water sampling in the Clark Fork Basin since September, 1985. The monitoring network utilized in 1988-1989 consisted of 32 fixed water quality monitoring stations on the Clark Fork River, its major tributaries, and wastewater discharges from Silver Bow Creek in Butte to below the Cabinet Gorge Dam in Idaho. Samples were collected 16 times each year from these stations.

Samples collected during this investigation were analyzed for chemical, physical, and biological parameters. Evaluations of the physical and chemical data are included in this report. Evaluations of the biological analytical data are described in Bahls (1989) and McGuire (1989a, 1989b).

Ingman and Kerr (1989)

This is an interim report prepared for the Section 525 Clean Water Act Study Steering Committee on nutrient pollution in the Clark Fork River Basin. The report is based on data developed through routine sampling in the Clark Fork River by the Montana Water Quality Bureau as described under Ingman and Kerr (1990).

Johnson and Schmidt (1988)

This project was completed by the Montana Governor's Office to devise an action plan for the Clark Fork River Basin. The report describes the present status of the Clark Fork Basin and outlines actions needed to restore and maintain water resources for future needs. Chapters in the report address the following topics:

- History of the basin's development, including events and activities that led to existing environmental conditions.
- Current water uses in the basin, including some indication of how these uses cost and benefit Montana.
- Environmental issues affecting the basin's water resources.
- Future water uses in the basin.
- Specific issues associated with the basin and proposed alternative actions to address these issues.

McGuire (1989a)

This report describes the results of an aquatic macroinvertebrate survey completed in the Clark Fork River in 1987. Data used to support this report were collected by the Montana Water Quality Bureau in conjunction with routine surface water sampling described under Ingman and Kerr (1990).

McGuire (1989b)

This report describes the results of an aquatic macroinvertebrate survey completed in the Clark Fork River in 1988. Data used to support this report were collected by the Montana Water Quality Bureau in conjunction with routine surface water sampling described under Ingman and Kerr (1990).

Schafer and Associates

This firm is completing a demonstration project for the Montana Governor's office to determine feasible means of stabilizing and amending streamside tailings along the Clark Fork River. The demonstration site is located in the Clark Fork River floodplain north of the Warm Springs Ponds. The project was initiated in 1989 and involves deep-plow incorporation of soil amendments to fix metals in the tailings and provide a suitable growth medium. Currently, the site is being monitored to evaluate the effectiveness of the remedial alternative implemented at the site. A report describing the project and results is forthcoming.

U.S. Geological Survey (1988) (1989) (1990)

These data reports contain streamflow data for designated gages on the Clark Fork River and its major tributaries for water years 1987, 1988, and 1989. Data included in these reports include mean daily flow, mean monthly flow, and historic mean flow.

Watson (1989a)

In this study, Watson evaluated levels of attached algae which are considered unacceptable, determined maximum levels of attached algae in the Clark Fork River, researched factors which limit growth and standing crop of attached algae in the Clark Fork River, and determined how much algal standing crops increase or decrease with changes in nutrient levels. The paper concluded that nuisance levels of attached algae are exhibited throughout much of the upper and middle Clark Fork River.

Watson (1989b)

During this study, predawn dissolved oxygen measurements were obtained at seven stations in July and August, 1987 in the Upper Clark Fork River. A diurnal dissolved oxygen survey was also conducted at nine stations in late July, 1987. The study concluded that several sites on the Clark Fork River exhibited dissolved oxygen levels at or below the state standard several times during the summer of 1987. In addition, the study found that the lowest dissolved oxygen levels occurred in late July between midnight and 2 a.m.

Certain other documents germane to Clark Fork River studies have been generated. A list of these documents is included in Section 5.0 as a supplemental reference list.

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